NEW ENGLAND WATER WORKS ASSOCIATION.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

WATER-WORKS STATISTICS FOR THE YEAR 1909, IN FORM ADOPTED BY THE NEW ENGLAND WATER WORKS ASSOCIATION.

COMPILED BY RICHARD K. HALE, EDITOR, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION.

The tables presented herewith contain statistics of forty-five municipal water works, as summarized in their annual reports. There are other water works which summarize their statistics, but the compiler has not succeeded in obtaining their reports for the year 1909.

The report of the Committee on Uniform Statistics, containing the form as endorsed for use in the 1901 reports, is printed on page 51 of Vol. XV of the JOURNAL (March, 1902). The page for Financial Statistics was changed by vote of the Association in September, 1902, as reported in the December, 1902, JOURNAL (Vol. XVI, p. 263). Blank forms for use in preparing summaries are printed by the Association, and will be furnished on request.

Previous compilations of statistics may be found in the JOURNAL, as follows:

Statistics for	Reference to Journal.
1886	Vol. I, No. 4, p. 29
1887	Vol. II, No. 4, p. 28
1888 to 1892 inclusive	Vol. VII, p. 225
1893	Vol. IX, p. 127
1894	Vol. X, p. 131
1895–96	Vol. XII, p. 273
1897–99	Vol. XV, p. 65

Statistics for	Reference to Journal.
1900	Vol. XV, p. 367
1901	Vol. XVI, p. 223
1902	Vol. XVII, p. 235
1903	Vol. XVIII, p. 277
1904	Vol. XIX, p. 241
1906	Vol. XXI, p. 191

In the various tabulations, statistics are given for the following places and years:

Place.	Year.
Albany, N. Y.	1900
Andover, Mass.	1900
Arlington, Mass.	1900, 1904, 1906, 1909
Atlantic City, N. J.	1898, 1900–04
Attleboro, Mass.	1894–1904, 1906, 1909
Bay City, Mich.	1886–87, 1893–96, 1900–04
Belmont, Mass.	1902–04, 1906
Beverly, Mass.	1903, 1906
Billerica, Mass.	1899–1904, 1906, 1909
Boston, Mass.	1886–94, 1897, 1900, 1903, 1909
Bridgeport, Conn.	1904
Brockton, Mass.	1893–1904, 1906, 1909
Burlington, Vt.	1886–1904, 1906, 1909
Cambridge, Mass.	1900–04, 1906, 1909
Chelsea, Mass.	1900–04, 1906, 1909
Cleveland, Ohio	1902–04, 1906
Concord, N. H.	1895, 1898, 1900–04
Detroit, Mich.	1909
Dover, N. H.	1900, 1909
East Orange, N. J.	1909
Erie, Pa.	1900
Essex Junction, Vt.	1900
Fall River, Mass.	1886–95, 1897–1904, 1906, 1909
Fitchburg, Mass.	1886–92, 1894–1904, 1906, 1909
Framingham, Mass.	1909
Freeport, Me.	1901
Geneva, N. Y.	1900
Gloucester, Mass.	1906, 1909
Harrisburg, Pa.	1906, 1909
Haverhill, Mass.	1900, 1904, 1906, 1909
Holyoke, Mass.	1886–92, 1897–98, 1900–04, 1906, 1909
Hull, England	1900
Ipswich, Mass.	1900
Keene, N. H.	1899–1900, 1903–04, 1909

Place.	Year.
Lawrence, Mass.	1902–04, 1909
Leicester, Mass.	1900
Leominster, Mass.	1900
Lewiston, Me.	1900
London, Ontario	1909
Louisville, Ky.	1909
Lowell, Mass.	1886, 1897–1904, 1906, 1909
Lynn, Mass.	1888–98, 1900–04, 1906
Madison, Wis.	1900, 1902–04, 1906, 1909
Manchester, N. H.	1900
Marlborough, Mass.	1900, 1903–04, 1906, 1909
Maynard, Mass.	1901–03
Metropolitan Water Works, Mass.	1900–04, 1906, 1909
Middleboro, Mass.	1895–1904, 1906
Middletown, Conn.	1902
Minneapolis, Minn.	1900–04, 1906
Nantucket, Mass.	1900
Nashua, N. H.	1900, 1904
New Bedford, Mass.	1886–1904, 1906, 1909
New London, Conn.	1886–1904, 1906, 1909
Newton, Mass.	1888–1904, 1906, 1909
Norwich, Conn.	1901
Oberlin, Ohio	1893–1904, 1906
Plymouth, Mass.	1886–1904, 1906, 1909
Portland, Ore.	1909
Providence, R. I.	1897–1904, 1906
Quincy, Mass.	1893, 1900–01
Reading, Mass.	1893, 1895–1904, 1906, 1909
Reading, Pa.	1901–04, 1906, 1909
Rochester, N. Y.	1903
St. John, N. B.	1902–03
Salem, Mass.	1900
Sandusky, Ohio	1886
Schnectady, N. Y.	1886, 1900–01
Somerville, Mass.	1900–04, 1906, 1909
Springfield, Mass.	1886–1904, 1906, 1909
Sydney, Cape Breton	1909
Taunton, Mass.	1886–1904, 1906
Toronto, Canada	1893
Trenton, N. J.	1886–87
Troy, N. Y.	1886, 1888–93, 1897–99
Waltham, Mass.	1886–1904, 1906
Ware, Mass.	1886, 1888–92, 1900–04, 1906, 1909
Watertown, Mass.	1900, 1909
Wellesley, Mass.	1888–93, 1898–1904, 1906, 1909
Westerly, R. I.	1902–04, 1906, 1909
Whitman, Mass.	1897–1904, 1906
Wilmington, Del.	1900
Winchendon, Mass.	1900–04, 1906, 1909
Woburn, Mass.	1900–04, 1909
Woonsocket, R. I.	1886–1900, 1902–04, 1906, 1909
Worcester, Mass.	1900, 1906, 1909
Yonkers, N. Y.	1893–96, 1900–04, 1906

1909. — TABLE 1. — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1	2. — Description of fuel used.				
						Builders of pumping machinery.	a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
1	Arlington, Mass.	1872 1894	Town.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
2	Attleboro, Mass.	1873	Town.	Wells.	Pumping.	Deane, Barr.	Bituminous.	.....	....	..	....
3	Billerica, Mass.	1898	Town.	Driven wells.	Pumping.	Barr.	Bituminous.	Pocahontas. New River. Orenda.	$4 52	..	....
4	Boston, Mass.	1848	City.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
5	Brockton, Mass.	1880 1902	City.	Silver Lake.	Pumping.	Barr, Holly.	Bituminous.	New River.	4 45	9.1	....
6	Burlington, Vt.	1867	City.	Lake Champlain.	Pumping.	Worthington.	Bituminous.	.....	3 80	..	....
7	Cambridge, Mass.	1855	City.	Hobbs Brook, Stony Brook, Fresh Pond.	Pumping.	Groshon, Worthington, Blake.	Bituminous.	Georges Cr. Orenda. New River.	3 90 3 68 3 90	..	....
8	Chelsea, Mass.	1867	City.	Metropolitan W.W.	.....	.....	.....	.....	....	..	....
9	Detroit, Mich.	1827	Water Com'rs.	Detroit River.	Pumping.	Detroit Loco., Riverside, Eng., Allis.	Bituminous.	Meadow Bk.	2 55	6.7	....
10	Dover, N. H.	1888	City.	Pond and springs.	Pumping.	Blake, Platt, Lawrence.	.....	Cumberland.	4 75	..	....
11	E. Orange, N. J.	1882	City.	Wells.	Pumping.	Snow.	Buckwheat.	Scranton.	2 75	18	....
12	Fall River, Mass.	1874	City.	N. Watuppa Lake.	Pumping.	Worthington, Davidson.	Bituminous.	Cumberland. Georges Cr.	....	..	....
13	Fitchburg, Mass.	1873	City.	Storage reserv'rs.	Gravity.	.....	.....	.....	....	..	....
14	Framingham, Mass.	1885	Town.	Filter galleries, Sudbury Aque.	Pumping.	Deane.	Bituminous.	Pocahontas.	4 15	10	....

15	Gloucester, Mass.	1884	City.	Reservoirs.	Pumping.	Knowles, Barr.	Bituminous.	Georges Cr.	4 25	8	....
16	Harrisburg, Pa.	1843	City.	Susquehanna R. (filtered).	Pumping.	Barr, Harrisburg	Anthracite.	Pea.	1 25	17	....
17	Haverhill, Mass.	..	City.	Ponds.	Gravity and pumping.	Worthington, Deane, Barr, Platt, Laidlaw-Dunn-Gordon.	Bituminous.	Cumberland. Carbon.	4 71	..	....
18	Holyoke, Mass.	1873	City.	Lakes, reservoirs and Manhan R.	Gravity.	.....	.....	.....	....	..	....
19	Keene, N. H.	1868	City.	Lakes.	.....	.....	.....	.....	....	..	....
20	Lawrence, Mass.	1874	City.	Merrimac River.	Pumping.	Barr, Morris.	Bituminous.	New River.	4 45	6.5	....
21	London, Ontario.	1878	City.	Springs.	Pumping.	Northey,* Kelly, Blake-Yates.	Steam.	W. Virginia.	4 25	..	....
22	Louisville, Ky.	1860	City.	Ohio River.	Pumping.	Cornish, Morris, Allis-Chalmers, Holly.	Bituminous.	E. Kentucky.	1 70 1 34	..	....
23	Lowell, Mass.	1870	City.	Driven wells.	Pumping.	Morris, Worthington, Deane, Knowles, Holly.	Bituminous.	Pocahontas. New River.	4 44	..	....
24	Madison, Wis.	1882	City.	Artesian wells.	Pumping.	Allis-Chalmers, Knowles.	Anthracite.	Pea.	7 10	..	....
25	Marlboro, Mass.	1883	City.	Lake and res.	Pumping.	Blake, Worthington, Barr.	Bituminous.	Various.	4 70	..	....

* Hydraulic.

1909. — TABLE 1, *Continued.* — GENERAL AND PUMPING STATISTICS.

Number.	Name of city or town.	Date of construction of works.	By whom owned.	Source of supply.	Mode of supply.	1	2. — Description of fuel used.				
						Builders of pumping machinery.	a Kind.	b Brand of coal.	c Av. price per gross ton.	d Per cent. of ash.	e Wood. Price per cord.
						Chestnut Hill	*High Service*	*Station.*			
						Holly, Allis, Quintard.	Bituminous.	New River. Blossburg. Imperial. Vulcan. Logan.	(1) $3 85 to 4 19	9.5	....
							Anthracite.	Buckwheat.	2 73	..	....
26	Metropolitan Water Works, Mass.	1848 1872 1895	State of Massachusetts.	L. Cochituate, Sudbury River, Nashua River.	Pumping, 75%. Gravity, 25%.	*Chestnut Hill*	*Low Service*	*Station.*	(2)		
						Holly.	Bituminous.	Vulcan.	3 86 to 4 06	9.6	....
							Anthracite.	Buckwheat.	2 61		
						Spot Pond	*Station.*		(3)		
						Blake, Holly.	Bituminous.	Davis.	4 19 to 4 25	13.2	....
							Anthracite.	Screenings.	2 24 to 2 50		
27	New Bedford, Mass.	1866	City.	Ponds.	Pumping.	Dickson.	Bituminous.	New River.	4 04	7	....
28	New London, Conn.	1872	City.	Lake and Res.	Gravity and pumping.	.....	.....	.....	....	..	....
29	Newton, Mass.	1876	City.	Collecting Gallery.	Pumping.	Barr, Worthington.	Bit'm's, 64%. Anth., 36%.	Radcliff. New River. Screenings.	3 79	14	$6 00
30	Plymouth, Mass.	1855	Town.	Ponds.	Gravity and pumping.	Barr, Worthington.	Bituminous.	Various.	5 00	..	....
31	Portland, Ore.	1893	City.	Bull Run River.	Gravity and pumping.	Smith & Vail, Gould, Holly, Reidler, Worthington.	Pumps operated by Pelton wheels.	.....	....	..	....

32	Reading, Mass.	1891	Town.	Filter gallery.	Pumping.	Blake.	Bituminous.	.....	4 75	..	....
33	Reading, Pa.	1819	City.	Creeks and springs.	Gravity and pumping.	Worthington, Allis-Chalmers.	Bituminous.	.....	2 53	8.1	3 50
34	Somerville, Mass.	1868	City.	Metropolitan W. W.	.....	.....	.....	.....	....	..	....
35	Springfield, Mass.	1864	City.	Res. and Little R.	Gravity.	.....	.....	.....	....	..	....
36	Sydney, C. B.	1892	City.	Reservoirs.	Gravity.	.....	.....	.....	....	..	....
37	Taunton, Mass.	1876	City.	Ponds.	Pumping.	Holly, Allis.	Bituminous.	Georges Cr. Cumberland.	4 80 4 45	..	....
38	Ware, Mass.	1886	Town.	Wells.	Pumping.	Deane, Warren.	Bituminous.	.....	5 00	..	4 50
39	Watertown, Mass.	1884	Town.	Metropolitan.	.....	.....	.....	.....	....	..	....
40	Wellesley, Mass.	1884	Town.	Wells.	Pumping.	Blake.	Bituminous.	New River.	4 20	11.8	3 50
41	Westerly, R. I.	1886	Town.	Driven wells.	Pumping.	Worthington.	Bituminous.	Georges Cr.	5 00	..	....
42	Winchendon, Mass.	1896	Town.	Well.	Pumping.	Blake, Laidlaw-Dunn-Gordon.	Bituminous.	.....	4 70	12.3	....
43	Woburn, Mass.	1872	City.	Filter gallery.	Pumping.	Worthington, Blake.	Bituminous.	.....	4 92	9	....
44	Woonsocket, R. I.	1884	City.	Crook Fall Brook.	Pumping.	Worthington, Deane, Builders I. Fdy.	Bituminous.	Pocahontas.	4 58	9.1	3 00
45	Worcester, Mass.	1845	City.	Reservoirs	Gravity.	.....	.....	.....	....	..	....

[1] Average price per gross ton, $3.70.
[2] Average price per gross ton, $3.44.
[3] Average price per gross ton, $3.43.

1909. — TABLE 1, *Concluded.* — PUMPING STATISTICS.

Number.	3 Coal consumed for the year. (Lbs.)	4 Lbs. of wood ÷ 3 = equivalent coal.	4a Amount of other fuel used.	5 Total equivalent coal consumed for the year. (Lbs.) (3) + (4).	6 Total pumpage for the year in gallons.	7 Average static head against which pumps work. (Feet.)	8 Average dynamic head against which pumps work. (Feet.)	9 Number of gallons pumped per lb. of equivalent coal.	10 Duty in foot-pounds per 100 pounds of coal. No deductions.	11 Cost per million gallons pumped into reservoir, figured on pumping station expenses.	12 Cost per million gallons raised 1 foot high, figured on pumping station expenses.
2	1 044 639	.....	.....	1 044 639	301 612 468	...	261	289	71 020 000	.....	.....
3	360 985	.....	.....	360 985	39 748 276[1]	300	322	132	29 656 316	$57 31	$0 18
5	2 203 268	.....	.....	2 203 268	856 290 553[1]	202	302	388	97 997 061	11 57	0 04
6	2 783 986	.....	.....	2 783 986	364 864 346[1]	289	316	131	34 539 616	24 74	0 08
7	4 642 700	500	.....	4 643 200	5 678 588 720[1]	157	189	792	125 084 465	4 69	0 02
9	36 066 844	.....	.....	36 066 844	27 816 750 890[2]	...	132	771	87 945 076	3 33	0 01
10	210 735	.....	193 203[3]	.....	272 805 000[1]	159	182	289	43 512 435	17 12	0 09
								1 095	166 345 758		
11	4 249 700	.....	.....	4 249 700	1 155 614 900	204	217	272	49 400 000	15 89	0 07
12	4 258 000	.....	.....	4 258 000	1 949 261 817	186	...	409	.....	8 77	....
14	916 400	200	.....	916 600	205 453 000[2]	201	205	224	38 484 918	20 79	0 10
15	937 737	.....	.....	937 737	502 204 723[1]	117	140	502	62 530 777	13 67	0 10
16	10 416 138	.....	.....	10 416 138	3 659 543 150[1]	200	235	363	72 329 958	4 51	0 02
17	2 169 164	.....	.....	2 169 164	1 104 690 737[2]	190	204	290	86 645 206	12 63	0 62
								589			
20	288 788	.....	.....	288 788	94 957 360	293	321	329	88 009 276	24 78	0 08
	2 420 254	.....	.....	2 420 254	1 206 390 311	154	186	497	76 478 736	10 80	0 06
21	2 994 700	.....	.....	2 994 700	1 561 355 262[4]	...	240	274	54 786 260	8 35	0 04
22	{ 12 930 589 }	.....	.....	25 317 485	9 111 827 126	...	199	705	111 767 000	3 44	0 02
	{ 12 386 896 }				7 957 890 859	...	112	642	60,500 000	2 82	0 02
23	5 546 723	2 400	.....	5 549 123	1 909 792 832	157	164	344	78 340 873	16 29	0 10
24	3 370 700	.....	.....	3 370 700	617 317 000	201	231	...	.....	42 69	0 18
25	842 322	.....	.....	842 322	208 933 300[2]	173	176	...	41 370 654	18 50	0 10
*26*a*	2 124 272	.....	.....	2 124 272	1 321 950 000a	...	120	622	64 270 000	5 68	0 05
b	1 565 681	.....	.....	1 565 681	1 404 590 000[2]	...	128	897	103 220 000	4 65	0 04
c	8 625 393	.....	.....	8 625 393	10 708 460 000[2]	...	130	1 241	138 840 000	3 03	0 02
d	7 160 584	.....	.....	7 160 584	19 183 420 000[2]	...	46	2 679	105 380 000	1 68	0 04
e	2 424 886	.....	.....	2 424 886	2 693 510 000[2]	...	130	1 111	123 760 000	5 22	0 04
27	3 104 725	.....	.....	3 104 725	2 718 298 758[2]	168	184	875	134 757 873	6 61	0 04

29	2 061 680	2 000	0	2 063 680	855 175 662[2]	234	263	414	90 893 908	11 84	0 04
30	431 940	.....	.....	431 940	249 968 100	65	70	589	25 558 000	11 51	0 16
								438	34 340 000		
31	.....	.....	.....	.....	.....	175 to 565	150 to 570	...	.....	.....	.....
32	580 249	.....	.....	580 249	67 920 004[2]	219	240	117	23 429 369	44 05	0 18
33	7 246 500	1 800	.....	7 248 300	2 905 448 577[1]	212	287	401	95 878 721	5 28	0 02
37	2 208 500	.....	.....	2 208 500	792 767 691[2]	...	...	...	.....	10 93	....
38	814 820	1 100	.....	815 920	158 447 880[1]	230	252	194	40 923 955	29 10	0 12
40	722 100	100	.....	722 200	118 198 000	260	280	164	38 219 000	30 29	0 11
41	1 449 312	.....	.....	1 449 312	246 059 400[2]	217	232	176	32 850 000	26 53	0 11
42	402 007	.....	.....	402 007	53 246 636[2]	246	289	132	31 924 000	30 11	0 10
43	2 469 200	.....	.....	2 469 200	660 405 240[2]	214	216	267	48 292 334	15 22	0 07
44	1 134 900	1 729	.....	1 136 629	542 596 731[1]	226	246	477	97 939 887	10 58	0 04

* 26*a*. C. H. H. S. Station, engines 1 and 2.
b. C. H. H. S. Station, engine 3.
c. C. H. H. S. Station, engine 4.
d. C. H. L. S. Station, engines 5, 6, and 7.
e. Spot Pond Station, engines 8 and 9.

a. Kirtland Street Station.

[1] Without allowance for slip.
[2] With allowance for slip.
[3] K.W.
[4] Imperial gallons. 646 319 273 imperial gallons pumped by water power.

1909. — TABLE 2. — FINANCIAL STATISTICS.

Number.	Name of city or town.	Receipts.						
		Balance brought forward.		Water rates.			Municipal departments.	
		a From ordinary receipts.	b From extraordinary receipts.	A Fixture rates.	B Meter rates.	C Total from consumers.	D For hydrants.	E For fountains.
1	Arlington, Mass.	.....	.....	$14 600 78	$24 017 62	$38 618 40	.....	.....
2	Attleboro, Mass.	$2 549 80	.....	.....	.....	42 055 27	.....	.....
3	Billerica, Mass.	.....	.....	1 245 66	3 421 13	4 666 79	$2 300 00	.....
4	Boston, Mass.	.....	.....	1 348 800 77	1 260 301 62	2 609 102 39	.....	.....
5	Brockton, Mass.	.....	$35 704 35	459 00	109 474 53	109 933 53	.....	.....
7	Cambridge, Mass.	.....	.....	.....	.....	361 896 86	.....	.....
8	Chelsea, Mass.	.....	.....	38 085 26	71 919 12	110 004 38	.....	.....
9	Detroit, Mich.	72 879 98	.....	398 220 75	229 956 90	628 177 65	.....	.....
10	Dover, N. H.	9 434 14	.....	11 648 98	16 797 25	28 446 23	.....	.....
11	East Orange, N. J.	8 683 80	16 083 92	103 081 84	23 352 91	126 434 75	.....	.....
12	Fall River, Mass.	27 993 73	.....	2 364 23	203 072 82	205 437 05	.....	.....
13	Fitchburg, Mass.	.....	.....	13 489 94	67 993 90	.....	.....	.....
14	Framingham, Mass.	.....	.....	1 875 56	29 711 57	31 587 13	3 733 11	$280 00
15	Gloucester, Mass.	1 251 43	.....	74 136 50	19 921 91	94 058 41	.....	.....
16	Harrisburg, Pa.	.....	.....	29 570 53	155 442 30	185 012 83	.....	.....
17	Haverhill, Mass.	34 772 28	.....	72 129 85	27 412 97	99 542 82	.....	.....
18	Holyoke, Mass.	15 758 30	.....	81 555 96	33 417 64	114 973 60	.....	.....
19	Keene, N. H.	.....	.....	.....	.....	28 324 32	6 525 00	500 00

20	Lawrence, Mass.	8 677 12	.....	.....	.....	129 637 41	.....	.....
22	Louisville, Ky.	.....	.....	401 633 31	300 455 30	702 088 61	.....	.....
23	Lowell, Mass.	.....	.....	23,964 98	163 053 40	187 018 38	.....	.....
24	Madison, Wis.	399 85	5 125 14	.....	.....	40 652 44	.....	.....
25	Marlboro, Mass.	338 30	.....	10 310 29	28 801 06	39 111 35	6 760 00	.....
27	New Bedford, Mass.	37 203 33	22 662 28	77 928 99	142 079 55	220 008 54	.....	.....
28	New London, Conn.	53 901 04	.....	.....	.....	63 499 36	13 680 00[1]	900 00[1]
29	Newton, Mass.	7 335 00	13 066 66	1 822 00	138 965 00	140 787 00	.....	.....
30	Plymouth, Mass.	2 686 46	.....	.....	.....	36 611 90	.....	.....
31	Portland, Ore.	110 968 72	.....	.....	.....	570 730 60	.....	.....
32	Reading, Mass.	279 67	.....	.....	13 813 55	13 813 55	5 040 00	300 00
33	Reading, Pa.	62 426 97	203 917 66	160 018 64	70 453 63	230 472 27	.....	.....
34	Somerville, Mass.	.....	.....	113 341 33	109 773 59	223 114 92	.....	.....
35	Springfield, Mass.	82 267 95	179 084 19	101 335 37	197 114 11	298 449 48	30 250 00[1]	645 00[1]
37	Taunton, Mass.	.....	2 711 75	.....	.....	78 555 25	.....	.....
39	Watertown, Mass.	1 975 14	533 78	.....	49 858 08	49 858 08	.....	.....
40	Wellesley, Mass.	4 771 82	2 566 39	240 00	18 573 15	18 813 15	4 000 00[2]	.....
41	Westerly, R. I.	6 467 37	.....	2 789 32	27 530 09	30 319 41	3 278 45	.....
42	Winchendon, Mass.	6 302 05	.....	35 00	8 818 30	8 853 30	4 960 00	333 33
43	Woburn, Mass.	.....	.....	41 788 19	11 359 51	53 147 70	.....	275 00
44	Woonsocket, R. I.	.....	.....	2 472 66	83 244 15	85 716 81	18 685 00	2 111 94

[1] Book account only.

[2] Includes fountains and street watering.

1909. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number.	Receipts — *Continued.*								
	Municipal departments — *Continued.*								
	F For street watering.	G For public buildings.	H For miscellaneous uses.	I General appropriation.	J Total from municipal departments.	K From tax levy.	L From bond issue.	M From other sources.	N Total receipts.
1	.....	.....	.....	.....	.....	$7 000 00	$2 000 00	$6 188 09	$53 736 49
2	.....	.....	.....	$6 200 00	.....	.....	15 000 00	.....	65 805 07
3	.....	$159 98	$13 00	.....	$2 472 98	4 548 33	.....	157 71	11 845 81
4	.....	.....	.....	.....	.....	218 563 49	.....	69 969 60	2 897 635 48
5	$2 000 00	.....	779 19	.....	2 779 19	.....	62 500 00	8 080 29	218 997 36
7	.....	.....	.....	.....	.....	.....	.....	21 839 15	383 736 01
8	.....	.....	.....	20 000 00	20 000 00	.....	.....	2 140 16	132 145 54
9	.....	.....	.....	.....	.....	75 000 00	300 000 00	103 823 98	1 179 881 61
10	.....	.....	.....	.....	.....	4 000 00	.....	1 852 55	43 732 92
11	.....	.....	.....	.....	.....	.....	.....	23 953 98	175 156 45
12	.....	.....	.....	.....	.....	.....	.....	5 538 86	238 969 64
13	.....	.....	.....	.....	.....	.....	.....	7 183 82	88 667 66
14	827 89	364 16	.....	.....	5 205 16	.....	40 188 00	2 380 93	79 361 22
15	.....	.....	.....	.....	17 855 00	.....	32 770 37	3 446 24	149 774 62
16	.....	.....	.....	.....	.....	.....	.....	4 170 26	189 183 09
17	.....	.....	.....	.....	.....	.....	.....	.....	145 663 35
18	.....	.....	.....	.....	.....	.....	.....	8 442 92	139 174 82
19	2 000 00	250 00	50 00	.....	9 375 00	.....	.....	.....	37 699 32

20	1 841 17	.....	.....	.....	1 841 17	.....	.....	9 618 27	149 773 97
22	.....	.....	.....	.....	.....	.....	.....	8 129 34	710 217 95
23	1 500 00	4 034 46	.....	.....	5 534 46	17 800 00	.....	20 165 31	230 518 15
24	.....	.....	.....	.....	.....	10 000 00	35 108 89	4 674 32	95 963 02
25	.....	181 04	32 48	.....	6 973 52	.....	.....	2 155 07	48 578 24
27	.....	.....	.....	.....	.....	.....	.....	.....	279 874 15
28	2 500 00[1]	1 500 00[1]	.....	.....	18 580 00[1]	.....	.....	.....	135 980 40
29	550 00	2 888 00	.....	.....	3 438 00	.....	.....	.....	164 626 66
30	.....	.....	.....	.....	.....	.....	12 053 87	1 013 95	52 366 18
31	.....	.....	.....	.....	.....	.....	250 000 00	5 217 50	936 916 82
32	500 00	.....	.....	860 00	6 700 00	.....	4 350 00	1 641 60	26 754 82
33	[2]	.....	.....	.....	.....	.....	208 763 29	11 039 05	716 619 24
34	.....	.....	.....	.....	.....	.....	.....	15 076 10	238 191 02
35	7 116 12[1]	14 645 53[1]	5 424 05[1]	.....	58 080 70[1]	.....	1 103 778 51	57 284 49	1 778 945 32
37	.....	.....	.....	.....	.....	22 000 00	.....	6 110 31	109 377 31
39	.....	.....	.....	9 600 00	9 600 00	.....	.....	1 644 72	63 611 72
40	[3]	261 40	.....	.....	4 261 40	.....	15 461 34	1 850 44	47 724 54
41	13 68	.....	.....	.....	3 292 13	.....	.....	2 425 94	42 504 85
42	168 54	.....	.....	.....	5 461 87	8 200 00	.....	45 50	28 862 72
43	250 00	255 00	.....	.....	780 00	.....	.....	.....	49 928 11
44	2 035 39	1 775 64	744 84	10 000 00	35 352 81	.....	.....	3 863 41	124 933 03

[1] Book account only.

[2] Included in meter rates.

[3] Included in "Hydrants."

1909. — TABLE 2, *Continued.* — FINANCIAL STATISTICS.

Number.	Maintenance Expenditures.			DD	EE	FF	Construction Expenditures.				
	AA	BB	CC				GG	HH	II	JJ	KK
	Operation.	Special.	Total maintenance.	Interest on bonds.	Payment of bonds.	Sinking fund.	Extension of mains.	Extension of services.	Extension of meters.	Special.	Total construction.
1	$6 898 44	$17 442 46[1]	$24 340 90	$13 920 00	.....	$10 000 00	$2 000 00	$983 74	$1 298 98	.....	$4 282 72
2	.....	.....	36 062 59	.....	.....	10 000 00	11 631 61	3 486 97	1 454 61	$3 092 19	19 665 38
3	.....	.....	2 936 26	3 600 00	.....	1 800 00	2 866 29	205 59	2 20	.....	3 074 08
4	.....	.....	871 367 43	161 963 39	.....	.....	.....	.....	.....	.....	(*A*)
5	42 510 72	.....	42 510 72	63 641 25	.....	6 548 63	33 171 52	6 840 60	3 490 28	39 960 00	83 462 40
7	.....	.....	73 930 64	145 050 25	$12 500 00	120 999 50	.....	.....	1 999 86	33 681 73	35 681 59
8	8 686 93	51 499 13[1]	60 186 06	12 000 00	.....	5 409 00	.....	.....	8 219 20	26 856 20	.....
9	.....	.....	182 163 74	37 273 50	10,000 00	75 000 00	764 971 99	.....	14 653 03	41 777 68	821 402 70
10	12 039 57	.....	12 039 57	9 755 86	5 000 00	.....	877 67	1 272 48	662 07	8 701 55	11 513 77
11	45 765 37	14 482 77	60 248 14	35 850 00	.....	18 000 00	12 815 00	.....	1 032 80	20 564 52	34 412 32
12	.....	.....	60 444 89	51 730 00	.....	39 835 00	24 990 22	4 343 14	.....	43 614 67	72 948 01
14	.....	.....	12 894 38	18 010 00	.....	.....	18 305 63	(*A*)	4 670 65	6 145 49	29 121 77
15	.....	.....	22 295 78	40 955 00	50 000 00	.....	1 106 88	7 082 60	.....	5 135 03	13 324 51
16	49 260 54	16 284 87	65 545 41	31 676 00	.....	39 888 30	.....	.....	.....	.....	.....
17	27 890 72	.....	27 890 72	38 640 00	5 000 00	18 000 00	12 048 57	5 833 60	1 964 79	9 208 48	29 055 44
18	.....	.....	131 768 45	13 750 00	.....	10 000 00	5 412 63	.....	350 00	9 652 09	15 414 68
19	.....	.....	2 214 35	3 742 50	.....	.....	.....	.....	.....	.....	.....

20	44 219 96	17 692 04	61 912 00	28 480 00	.....	16 457 65	.....	.....	.....	.....	28 837 42
22	.....	.....	217 611 56	79 034 63	.....	.....	.....	.....	.....	.....	.....
23	118 333 70	.....	118 333 70	44 571 00	15 200 00	17 800 00	10 714 90	5 236 08	.....	.....	15 950 98
24	22 844 94	3 333 69	26 178 63	.....	.....	.....	.....	.....	.....	.....	21 640 06
25	9 999 46	200 00	10 199 46	20 800 00	.....	.....	.....	.....	.....	.....	2 531 79
27	55 129 78	.....	55 129 78	62 980 00	30 000 00	28 338 00	33 434 83	12 489 18	13 134 60	228 14	59 286 75
28	11 940 49	.....	11 940 49	23 665 00	.....	.....	7 173 40	901 45	1 877 85	7 591 49	17 544 19
29	22 222 00	6 525 00	28 747 00	54 338 00	4 000 00	34 000 00	17 938 37	12 411 29	3 778 38	13 413 32	47 541 36
30	.....	.....	11 144 01	5 820 48	11 666 66	.....	14 926 65	449 92	203 50	4 858 85	20 438 92
31	103 834 99	.....	103 834 99	160 000 00	.....	63 000 00	50 378 62	.....	84 643 74	188 896 88	323 919 24
32	7 266 31	718 42	7 984 73	7 625 00	1 000 00	.....	6 663 04	2 664 49	634 28	133 45	10 095 26
33	65 614 23	1 224 00	66 838 23	35 980 00	.....	50 023 85	28 741 95	987 73	5 381 04	258 263 62	293 374 34
34	25 733 77	11 281 41	37 015 18	2 460 00	6 000 00	.....	7 553 90	4 279 06	6 131 44	.....	18 014 40
35	67 198 58	26 750 10	93 948 68	58 875 00	.....	30 454 47[2]	111 153 39	.....	.....	1 092 277 12	1 203 430 51
37	.....	.....	33 574 77	33 890 00	.....	11 977 34[2]	8 980 09	3 807 10	1 517 17	14 774 71	29 079 07
39	4 736 08	15 758 18[1]	20 494 26	11 400 00	14 000 00	.....	2 952 94	2 946 33	1 151 99	.....	7 051 26
40	7 704 60	113 79	7 818 39	11 280 00	.....	.....	4 679 45	1 012 19	.....	12 343 36	18 035 00
41	11 129 57	.....	11 129 57	13 368 39	.....	6 000 00	2 510 67	1 452 13	570 89	2 030 84	6 564 53
42	4 564 59	.....	4 564 59	3 040 00	.....	.....	6 260 03	363 28	506 88	6 080 97	13 211 16
43	.....	.....	20 607 56	2 780 00	.....	25 782 84[2]	.....	.....	.....	.....	757 71
44	18 151 06	.....	18 151 06	.....	.....	.....	.....	.....	.....	.....	10 718 43

[1] Metropolitan water-works assessment.

[2] Maintenance balance.

(*A*) Included in maintenance.

1909. — TABLE 2, *Concluded.* — FINANCIAL STATISTICS

Number.	LL	MM Balance.		N		O	P	Q	R
	Unclassified expenses.	*aa* Ordinary	*bb* Extraordinary.	Total.	Disposition of balance.	Net cost of works to date.	Bonded debt at date.	Value of sinking fund.	Average rate of interest. Per cent.
1	.....	$1 192 87	.....	$53 736 49	.....	$538 737 48	$355 000 00	$78 000 00	4
2	.....	77 10	.....	65 805 07	.....	713 180 14	552 000 00	74 794 56	.....
3	.....	.....	$435 47	11 845 81	.....	95 793 44	90 000 00	.....	.....
4	$1 864 204 66	.....	.....	2 897 635 48	.....	15 593 943 60	3 696 500 00	3 205 159 65	3.89
5	.....	22 834 36	.....	218 997 36	Forward.	1 874 851 28	1 702 500 00	624 903 27	3.7
7	4 307 08	.....	.....	.....	.....	6 491 201 12	3 751 600 00	1 892 859 62	3½–4
8	18 55	13 811 82	5 644 71	132 145 54	.....	541 749 39	300 000 00	142 016 00	4
9	28 689 83	25 351 84	.....	1 179 881 61	.....	9 645 904 60	1 180 000 00	97 910 85	3.5
10	.....	5 423 72	.....	43 732 92	.....	462 022 46	287 000 00	.....	3.75
11	2 862 21	7 699 86	16 083 92	175 156 45	.....	.....	.....	.....	.....
12	.....	14 011 72	.....	238 969 64	Forward.	2 216 155 38	1 250 000 00	393 903 48	3.56
13	51 529 13	37 138 53	.....	88 667 66	City treasury.	1 235 558 46	569 000 00	146 646 48	.....
14	.....	8 086 24	11 248 83	79 361 22	.....	485 455 08	492 000 00	38 500 00	4.06
15	18 212 44	4 986 89	.....	149 774 62	.....	1 428 670 17	1 109 000 00	.....	3½ and 4
16	2 757 20	49 322 18	.....	189 183 09	General fund.	1 275 000 00	789 700 00	239 111 73	3½
17	.....	27 077 19	.....	145 663 35	.....	1 484 271 75	961 000 00	387 126 98	4
18	.....	21 295 39	.....	139 174 82	.....	1 283 527 77	350 000 00	128 652 09	.....
19	.....	31 742 47	.....	37 699 32	.....	.....	98 000 00	.....	.....

20	.....	14 086 92	.....	149 773 97	.....	2 232 208 52	712 000 00	54 674 45	4
23	17 655 83	1 006 64	.....	230 518 15	Forward.	3 151 863 88	1 106 400 00	584 580 62	4
24	20 855 01	7 910 30	19 379 02	95 963 02	.....	575 755 81	80 000 00	.....	3½
25	.....	15 046 99	.....	48 578 24	.....	600 938 82	520 000 00	292 564 18	4
27	.....	44 139 62	.....	279 874 15	.....	3 512 321 09	1 488 000 00	510 780 16	4.16
28	40 000 00	42 830 72	.....	135 980 40	.....	1 168 152 47	651 000 00	.....	3.63
29	.....	3 999 70[2]	.....	.....	City treasury.	2 355 135 64	1 375 000 00	605 568 62	4
30	.....	3 296 11	.....	52 366 18	Forward.	444 018 88	148 999 84	.....	3.84
31	.....	286 162 61	.....	936 916 82	.....	5 800 266 95	3 400 000 00	240 310 14	4.7
32	.....	49 83	.....	26 754 82	Forward.	318 576 06	189 000 00	.....	4
33	4 088 12	45 366 68	220 948 02	716 619 24	Forward.	3 845 097 58	900 000 00	201 508 00	4
34	112 573 20[3]	62 128 24	.....	238 191 02	City treasury.	922 834 26	56 000 00	.....	4
35	36 638 87	159 991 49	195 606 30	1 778 945 32	Sinking fund.	4 157 244 57	2 095 000 00	175 000 00	3.7
37	.....	[4]	856 13	109 377 31	Forward.[4]	1 391 656 65	860 500 00	398 890 49	3.96
39	10 32	10 655 88	.....	63 611 72	.....	529 873 81	296 000 00	.....	3.85
40	5 461 11[1]	4 768 82	361 22	47 724 54	.....	383 249 47	287 000 00	153 276 89	4
41	.....	5 442 36	.....	42 504 85	.....	383 356 43	353 000 00	92 969 71	3.75
42	.....	8 046 97	.....	28 862 72	.....	161 442 60	73 000 00	.....	4
43	.....	[4]	.....	49 928 11	.....	.....	.....	.....	.....
44	.....	.....	96 063 54	124 933 03	.....	52 749 65	.....	.....	.....

[1] To city treasury. [2] Deficit. [3] Metropolitan water assessment. [4] Maintenance balance to sinking fund.

1909. — TABLE 3. — STATISTICS OF CONSUMPTION OF WATER.

Number.	Name of city or town.	1	2	3	4	5	6	7	8	9	10	11	12
		Estimated population.						Average consumption. (Gallons per day.)				Cost of supplying water. Per million gals.	
		Total at date.	On line of pipe.	Supplied at date.	Total consumption for the year. (Gallons.)	Quantity used through meters. (Gallons.)	Percentage of consumption metered.	Total.	To each inhabitant.	To each consumer.	To each tap.	Figured on total maintenance. (Item CC.)	Figured on total maintenance + int't on bonds.
1	Arlington, Mass.	11 500	10 600	10 500	[309 762 205	107 491 602	35	848 417	74	81	418	...	...
2	Attleboro, Mass.	18 000	17 000	....	301 612 468	.....	..	826 336	45	48	..	...	...
3	Billerica, Mass.	2 850	1 950	1 650	39 748 276	.....	..	108 900	..	66	..	$73 87	$164 44
5	Brockton, Mass.	63 400[1]	61 700[1]	60 700[1]	830 926 082	600 241 222	72	2 276 510	36	37	289	51 16	127 87
6	Burlington, Vt.	21 500	21 000	20 900	364 864 341	228 682 273	63	999 628	46	48	259	61 54	85 22
7	Cambridge, Mass.	103 000	103 000	103 000	3 678 588 720	.....	..	10 078 325	98	98	650	20 10	61 15
8	Chelsea, Mass.	35 475	35 475	35 475	1 047 331 000	461 040 000	44	3 316 900	81	81	..	57 44	68 90
9	Detroit, Mich.	440 618	458 175	455 029	27 816 750 890	8 768 974 646	36	76 210 276	167	168	876	6 54	7 89
10	Dover, N. H.	15,000	14 000	13 500	272 805 000	67 985 634	40	745 556	49	55	342	44 13	79 80
11	East Orange, N. J.	35 000	34 800	34 750	1 091 201 300	99 733 600	9	2 985 130	89	90	454	41 94	74 79
12	Fall River, Mass.	115 097	....	114 397	1 949 261 817	.....	..	5 340 443	46	47	..	...	...
13	Fitchburg, Mass.	....	....	....	1 095 000 000	.....	..	3 000 000	..	86	..	...	...
14	Framingham, Mass.	13 000	10 600	9 400	205 453 007	140 441 617	..	562 885	43	60	350	62 64	153 22
15	Gloucester, Mass.	38 000	35 000	22 000[2]	502 204 723	79 930 650	16	1 375 903	48	55	313	44 39	125 94
16	Harrisburg, Pa.	70 000	69 000	70 000	3 658 543 100	2 744 277 500	75	10 023 406	143	143	645	13 46	21 71
17	Haverhill, Mass.	45 000	42 408	42 000	1 753 477 338	204 498 285	11	4 804 047	106	114	763	15 91	37 95
18	Holyoke, Mass.	54 698	54 488	54 011	2 046 592 000	653 290 500	..	5 607 100	103	106	1 381	...	...
19	Keene, N. H.	11 000	10 000	9 000	.....	.....	.....	.....	...	...	...	...	...
20	Lawrence, Mass.	82 000	....	81 000	1 301 347 671	768 538 500	59	3 565 336	43	44	480	47 58	69 47
21	London, Ont.	50 000	....	....	.....	.....	..	.....	...	...	...	...	...
22	Louisville, Ky.	260 000	250 000	190 000	7 760 554 499	2 300 000 000	30	21 261 793	82	112	630	28 04	38 23
23	Lowell, Mass.	96 380	96 380	96 380	1 912 740 525	993 016 015	52	5 240 385	54	54	426	61 86	85 17
24	Madison, Wis.	29 906	....	26 976	617 317 000	263 522 167	..	1 691 279	56	65	..	...	...
25	Marlboro, Mass.	14 200	14 000	13 800	208 933 300	96 187 500	41	572 420	40	41	245	48 81	148 37
26	Met. W. W., Mass.	965 490	....	....	43 575 790 000	.....	..	119 386 000	124	...	..	...	...
27	New Bedford, Mass.	95 000	89 000	88 000	2 727 327 230	1 199 465 066	43	7 472 179	79	85	621	22 13	43 30
28	New London, Conn.	22 000	20 800	20 000	980 267 000	315 422 000	32	2 685 665	122	134	657	12 18	36 32
29	Newton, Mass.	39 750	39 400	39 200	855 802 436	562 000 000	66	2 344 664	59	60	292	...	...
30	Plymouth, Mass.	....	....	....	462 482 000	114 605 000	25	1 267 000	..	...	..	...	...
31	Portland, Ore.	275 000	196 700	196 700	.....	.....	..	.....	..	84	444	...	...
32	Reading, Mass.	5 760	5 685	5 300	67 920 004	42 083 496	62	186 082	32	351	138	117 54	229 82
33	Reading, Pa.	101 210	101 010	101 110	4 655 687 002	1 738 944 748	37	12 755 307	126	126	583	14 36	22 08

34	Somerville, Mass.	75 500	75 500	75 500	2 310 815 000	.....	..	6 331 000	84	..	..	...	...		
35	Springfield, Mass.	88 397	86 000	85 000	3 871 788 600	1 522 206 329	39	10 607 640	120	125	874	24	26	39	47
36	Sydney, C. B.	15 942	12 000	11 500	600 206 350	53 397 651	9	1 644 000	100	143	865	...		...	
37	Taunton, Mass.	30 967	30 000	30 000	792 767 691	367 643 000	46	2 171 966	70	72	415	42	35	85	10
38	Ware, Mass.	9 000	8 900	8 850	158 447 880	106 246 386	68	434 103	48	50	499	...		...	
39	Watertown, Mass.	12 630	12 600	12 600	275 721 000	185 059 200	67	755 400	60	60	382	74	32	115	67
40	Wellesley, Mass.	7 035	6 975	6 935	118 198 000	67 725 000	53	324 000	46	47	284	...		...	
41	Westerly, R. I.	13 500	12 000	11 000	246 059 400	.....	..	647 135	50	61	391	44	22	98	56
42	Winchendon, Mass.	6 200	4 150	3 643	53 246 636	24 030 439	45	145 504	23	40	189	85	72	142	81
43	Woburn, Mass.	14 400	19 300	14 300	660 405 240	79 573 950	12	1 809 329	126	..	...	...		...	
44	Woonsocket, R. I.	35 809	40 548	40 048	537 866 481	406 857 523	76	1 473 607	36	37	443	33	75	...	
45	Worcester, Mass.	146 417	144 417	144 417	3 238 662 500	2 265 052 985	70	8 873 048	61	62	385	24	49	68	68

[1] Including Whitman and Hanson.

[2] 12 000 extra during three summer months.

1909. — TABLE 4. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — MAIN PIPES.

Number.	Name of city or town.	1 Kind of pipe.	2 Sizes of pipes. (Inches.)	3 Length extended during the year. (Feet.)	4 Length discontinued during the year. (Feet.)	5 Total length in use. (Miles.)	6 Cost of repairs. (Per mile.)	7 Number of leaks. (Per mile.)	8 Length of pipe less than 4 in. diam. (Miles.)	9 Hydrants. Number added.	10 Hydrants. Total in use.	11 Gates. Number added.	12 Gates. Total in use.	13 Gates. No. smaller than 4-inch.	14 Gates. No. of blow-off gates.	15 Range of pressure on mains. (Pounds.)
1	Arlington, Mass.	C. I., Cem. L.	4–12	1 739	....	37	$1 40	....	0 8	4	384	3	319	....	....	50 & 90
2	Attleboro, Mass	C. I., W. I., Cem. L.	1–24	12 442	....	56	....	1	....	20	420	....	....	....	....	85–100
3	Billerica, Mass.	C. I.	6–12	3 746	....	10	....	4	....	5	108	....	84	....	4	54–120
4	Boston, Mass.	C. I., Cem. L.	2–48	63 327	20 781	761	[3]66 66	72	2	104	8 331	152	10 153	18	396	35–90
5	Brockton, Mass.	C. I., Cem. L.	6–30	14 218	....	110	2 72	0 34	8 9	42	996	93	1 469	142	47	47–56
6	Burlington, Vt.	Cem. L., C. I., W. I.	4–30	3 361	0	41	....	....	5	7	236	3	684	75	16	70–85
7	Cambridge, Mass.	C. I.	2–40	6 138	....	131	....	19	2	15	1 071	66	....	0	....	55–60
8	Chelsea, Mass.	C. I.	2–16	197	....	42	....	....	01	4	333	3	462	1	50	50–75
9	Detroit, Mich.	C. I.	2–48	154 039	25 665	752	2 54	0 13	10	396	5 243	352	7 954	21	961	8–62
10	Dover, N. H.	C. I.	3–16	2 976	0	27	....	....	2	....	189	3	264	0	8	68–114
11	East Orange, N. J.	C. I., W. I.	2–24	15 255	....	84	....	....	0 3	50	594	135	1 288	5	10	55–115
12	Fall River, Mass.	C. I.	6–24	.....	....	110	....	....	.....	41	1 278	42	1 310	....	....	80
13	Fitchburg, Mass.	C. I., W. I., Cem. L.	2–30	7 314	....	76	....	....	.....	19	631	22	708	....	....	86 & 165
14	Framingham, Mass.	C. I., W. I.	1–16	21 441	0	36	....	....	4	22	203	34	431	48	39	60–106
15	Gloucester, Mass.	C. I., Cem. L.	1–20	7 633	....	66	21 49	0 96	22	8	317	15	533	169	27	15–75
16	Harrisburg, Pa.	C. I.	6–42	16 835	....	67	....	3	.....	33	867	61	1 613	....	8	30–70
17	Haverhill, Mass.	C. I., Cem. L.	2–24	18 064	....	91	....	....	.....	2	361	53	1 025	....	....	30–120
18	Holyoke, Mass.	W. I., C. I., Ld. I.	½–30	4 332	2 46	91	8 58	8	6	4	946	31	993	20	42	60–100
19	Keene, N. H.	W. I., Cem. L., C. I.	4–24	3 454	736	41	....	....	3	4	261	3	400	....	31	50–65
20	Lawrence, Mass.	C. I.	1–30	13 369	1 758	95	0	0	8	27	756	83	1 426	0	....	65–125
21	London, Ont.	C. I.	2–20	7 466	1 038	98	....	0 06	5	17	619	25	643	16	5	40–90
22	Louisville, Ky.	C. I.	3–48	99 487	3 348	338	41 46	1 7	2	96	958	164	5 062	176	28	40–75
23	Lowell, Mass.	C. I.	4–30	9 965	....	143	2	....	.....	15	1 321	49	1 558	31	34	17–72
24	Madison, Wis.	C. I.	3–16	34 188	....	59	....	....	.....	40	350	79	487	....	3	53–65
25	Marlboro, Mass.	C. I.	4–16	0	0	37	0 79	0 11	0 89	0	354	0	394	19	65	35–142
26	Met. W. W., Mass.	C. I., Cem. L.	6–60	7 88[1]	....	92	....	....	.....	....	....	32	404	....	....	.....
	Met. Water Dist. (total in district supplied)	C. I., Cem. L., Kal.	4–60	33 77[1]	....	1 603	....	....	.....	276	14 355	....	....	....	....	.....
27	New Bedford, Mass.	C. I.	4–36	24 105	3 512	118	12 88	0 10	0 8	57	1 239	78	1 472	110	104	25–95
28	New London, Conn.	Cem. L., C. I.	4–24	2 293	0	69	5 76	0 3	4	7	370	12	535	....	41	45–70
29	Newton, Mass.	C. I.	4–20	6 422	0	145	1 40	1 4	3 5	9	996	12	867	53	429	80–86

30	Plymouth, Mass.	Cem. L., W. I.	2–20	12 807	10 478	52	12 43	0 96	10	10	258	44	586	141	41	.....	
31	Portland, Ore.	C. I., Steel, Wood.	2–30	55 477	12 700	324	....	....	63	...	....	194	2 316	311	138	20–80	
32	Reading, Mass.	C. I.	6–12	5 740	....	31	1 04	0	...	11	179	10	280	...	14	63–78	
33	Reading, Pa.	C. I.	2–36	6 758	1 508	114	19 72	0 61	04	7	965	26	2 905	4	(2)	10–133	
34	Somerville, Mass.	C. I.	4–20	7 114	....	94	....	0 12	...	18	1 103	32	1 454	...	141	35–100	
35	Springfield, Mass.	Cem. L., W. I., C. I.	1–54	104 782	35 998	175	5 98	0 18	6 44	40	1 367	301	3 240	553	92	30–135	
36	Sydney, C. B.	C. I.	4–24	4 130	....	27	5 59	0 48	0 16	...	148	12	210	2	17	68–87	
37	Taunton, Mass.	C. I.	4–20	6 219	0	86	28 11	0 20	1 5	15	965	19	666	12	63	50–120	
38	Ware, Mass.	C. I.	4–12	.....	.....	13	....	....	1 9	...	125	1	134	15	3	90–95	
39	Watertown, Mass.	C. I., Cem. L.	4–16	3 719	....	38	1 04	....	6	3	338	5	440	49	13	40–100	
40	Wellesley, Mass.	C. I., Cem. L.	1½–12	4 371	0	37	0 66	0 60	1	5	331	6	278	10	3	35–125	
41	Westerly, R. I.	C. I.	4–16	1 498	0	35	....	0 17	.....	1	167	2	220	4	...	40–92	
42	Winchendon, Mass.	C. I., W. I.	2–14	7 693	0	23	....	....	2 5	11	165	6	212	37	17	40–163	
43	Woburn, Mass.	C. I., Cem. L.	4–14	1 172	....	57	35 24	2 12	6	2	382	9	455	55	17	70–75	
44	Woonsocket, R. I.	C. I.	4–20	6 724	0	56	0 29	0 03	0	10	648	12	589	0	16	50–120	
45	Worcester, Mass.	.....	2–40	10 85[1]	....	220	....	....	.....	62	2 150	54	3 094	...	...	70–150	

[1] Miles.

[2] Included in items 12 and 13.

[3] Includes hydrants.

1909. — TABLE 5. — STATISTICS RELATING TO DISTRIBUTION SYSTEM. — SERVICE PIPES.

Number.	Name of city or town.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		SERVICE PIPE.					SERVICE TAPS.				METERS.				MOTORS & ELEVATORS.	
		Kind.	Sizes. (Inches.)	Extended. (Feet.)	Discontinued. (Feet.)	Total in use. (Miles.)	Number added.	Total in use.	Average length of services. (Ft.)	Average cost of services for the year.	Number added.	Now in use.	Percentage of services metered.	Percentage of receipts from metered water. (B) ÷ (C)	Added.	Total in use.
1	Arlington, Mass. . .	C. I., Galv. I., Cem. Lined.	¾–6	....	...	..	77	2 032	..	$17 26	129	1 121	55	62	..	4
2	Attleboro, Mass. . .	.....	..	...	...	..	...	2 234	..	....	145	2 246	...	....	..	2
3	Billerica, Mass. . . .	W. I., Cem. Lined.	1–1½	1 458	...	4	18	312	72	....	17	197	63	73	..	...
4	Boston, Mass.	Lead, Lead Lined Iron., C. I.	½–16	31 608	4 983	533	1 149	96 194	29	0 25	6 669	12 049	12	48	0	700
5	Brockton, Mass. . .	W. I., Ld. Lnd., Cem. Lnd., C. I.	¾–8	8 041	626	56	375	7 879	47 20	17 54 10 09	340	7 817	99	99	..	15
6	Burlington, Vt. . . .	Galv., C. I., Lead.	½–6	1 327	329	21	46	3 846	30	14 43	79	3 279	85	88	0	42
7	Cambridge, Mass. .	Galv., C.I., Tin Lnd., Lead Lnd.	¾–8	6 090	...	..	156	15 492	39	21 13	365	4 278	27	....	..	...
8	Chelsea, Mass.	Lead.	¾–2	3 007	...	34	99	4 601	30	14 61	855	2 210	48	65	0	3
9	Detroit, Mich.	Lead, C. I., Galv.	¾–10	....	....	..	3 683	86 649	..	....	509	7 956	9	....	0	36
10	Dover, N. H.	C. I., Cem. Lined.	1–8	1 604	0	18	27	1 884	43	....	104	1 004	53	58	0	9
11	East Orange N. J. .	Lead, W. I., C. I.	½–6	24 750	...	77	495	6 828	60	29 15	80	679	10	18	0	4
12	Fall River, Mass. .	Lead.	½–2	.....	...	..	217	8 316	..	....	236	8 197	...	....	..	...
13	Fitchburg, Mass. . .	W. I., Cem. Lined, C. I.	¾–8	.....	...	..	113	5 067	..	....	121	3 504	...	....	6	128
14	Framingham, Mass.	Lead, W. I., Galv., C. I.	¾–8	6 578	...	..	102	1 608	64	15 70	445	1 594	...	....	..	...
15	Gloucester, Mass. .	Cem. Lined, Galv.	1–6	3 059	0	17	152	4 390	21	32 97	13	237	5	16	..	...
16	Harrisburg, Pa. . . .	Lead, Galv.	¾–8	....	...	..	571	15 528	..	....	515	9 432	78	81	..	27
17	Haverhill, Mass. . .	Lead, W. I.	¾–4	10 267	266	49	192	6 294	48	22 96	125	974	15	28	..	20
18	Holyoke, Mass. . . .	Cem. Lnd., Rub. Lnd., Enam., Ld. Lnd., Tin Lnd., Galv.	½–6	1 401	5	16	89	4 061	20	16 89	25	351	...	....	..	157
19	Keene, N. H.	W. I., Lead, Galv.	¾–6	720	...	12	24	1 996	..	....	17	154	...	....	0	16
20	Lawrence, Mass. . .	Galv. Lead, C. I., Lead Lined.	¾–10	14 681	972	59	340	7 416	42	21 89	269	6 633	90	94	..	19
21	London, Ont.	Lead.	½	....	...	..	363	12 332	60	15 88	236	613	2	....	..	...
22	Louisville, Ky. . . .	Lead and Iron.	¾–6	....	...	..	1 433	33 731	30	12 73	244	2 642	8	43	..	...
23	Lowell, Mass.	Lead, Ld. Lnd., Tin Lnd., W. I.	¾–2	7 046	...	92	190	12 307	37	27 56	328	9 465	77	87	..	...
24	Madison, Wis.	Lead.	¾–1½	5 886	...	23	236	4 647	..	....	236	4 577	99	....	..	...
25	Marlboro, Mass. . . .	Cem. Lnd., Ld. Lnd., Lead, Galv.	½–2	881	0	10	33	2 336	27	15 46	53	1 557	67	73	0	19
26	Met. Water Dist. . .	.....	..	....	...	..	2 863	158 200	..	....	12 381	44 855	...	....	..	...
27	New Bedford, Mass.	Lead, C. I., W. I.	½–10	22 406	3 451	81	527	12 043	35	21 39	944	4 572	38	65	12	172
28	New London, Conn.	Cem. Lined, Galv., Lead.	¾–4	1 174	425	13	67	4 086	17	13 20	78	645	16	....	0	2
29	Newton, Mass.	Galv., Tarred I., Lead.	½–6	18 253	8 239	91	133	8 033	75	27 00	245	7 037	88	99	0	18
30	Plymouth, Mass. .	Lead, Cem. Lined.	½–4	635	...	7	55	2 415	12	8 18	....	89	4	....	0	1

31	Portland, Ore.....	Galv.	..	....	...	..	3 978	37 120	..	....	6 332	12 617	34	....	..	...
32	Reading, Mass....	C. I., Lead, Cem. Lined.	½–6	3 407	378	19	34	1 344	87	78 36	51	1 242	..	....	..	..
33	Reading, Pa.....	Lead, W. I., C. I., Lead Lined.	½–8	....	...	..	350	21 883[2]	..	....	450	3 020	14	31	142	273
34	Somerville, Mass. .	Lead, Ld.Lnd.,Cem. Lnd., C. I.	½–6	3 016	...	78	211	12 018	..	20 28	870	5 155	43	49	0	8
35	Springfield, Mass..	Lead, Cem. Lnd.,Tarred, Galv., C. I.	½–8	....	...	..	428	12 134	..	....	600	7 017	58	66	17	337
36	Sydney, Ont.....	Lead, Galv., C. I.	½–6	2 780	...	9	93	1 900	30	13 79	1	23	1	16	..	8
37	Taunton, Mass....	Cem. Lined, Tin Lined.	½–4	5 949	0	51	114	5 237	..	....	122	2 630	50	71	0	21
38	Ware, Mass.....	W. I., Cem. Lined.	1–2	622	...	10	10	870	62	....	18	884	93	....	..	12
39	Watertown, Mass..	W. I., Cem. Lnd. and Galv.	1–2	2 349	...	19	54	1 973	43	54 56	59	1 993	100	100	..	...
40	Wellesley, Mass...	C. I., Cem. Lnd., W. I., Lead, Ld. Lined.	½–8	4 886	233	22	61	1 140	75	9 46	....	....	100	...	..	...
41	Westerly, R. I.....	Lead, Iron.	½–6	2 139	0	..	37	1 724	10	18 66	37	1 466	85	....	0	12
42	Winchendon, Mass.	W. I., Cem. Lined.	1–2	2 710	0	7	55	770	49	6 60	55	770	96	99	0	1
43	Woburn, Mass....	Lead Lined, Cem. Lnd., Galv.	1	....	...	..	39	3 222	..	30 39	12	87	3	23	..	10
44	Woonsocket, R. I.	Lead, C. I.	⅜ 8	2 443	0	9	186	3 326	14	11 05	160	2 878	86	97	0	17
45	Worcester, Mass...	.....	..	....	...	15	507	....	..	....	490	15 599	..	....	..	...

[1] Deducted.

[2] Estimated.

DEPRECIATION, — IN WATER-WORKS OPERATION AND ACCOUNTING.

BY LEONARD METCALF.*

[*Read September 22, 1910.*]

That the author may not hereafter be charged with plagiarism he calls attention to the fact that a portion of this paper was written by him early in the year 1910, for insertion in a report (made by Mr. John W. Alvord, of Chicago, and the writer) upon the reproduction cost of the water works supplying one of the larger cities of the United States. It was subsequently used, in part, by Mr. Alvord (as stated by him at the New Orleans Convention of the American Water Works Association, held in April, 1910) as a basis for the progress report to that association of the "Committee upon Depreciation," of which he was the chairman and the writer was a member. The water company officials have courteously consented to the use of the material submitted to them, and it was thought that the fact that some of the opinions expressed had been reported to an operating company, as suggestions bearing upon its future government, might give it an added interest.

DEPRECIATION.

The fact that structures deteriorate with age and through other causes is well known to owners of property. Nevertheless, substantial recognition has not generally been given to this fact in the operation of water works, by providing a depreciation fund or account, to be earned by the rates, against which fund the cost of all abandoned structures and replacements should be charged. The decision of the Supreme Court of the United States upon the Knoxville Water Works case, delivered by Mr. Justice Moody,†

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† Thus Mr. Justice Moody says: "The company is not bound to see its property waste without making provision out of its earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that at the end of any given term of years the original investment remains as it was at the beginning. It is not only the right of the company to make such a provision, but it is its duty to its bond and stock holders, and, in the case of a public-service corporation at least, its plain duty to the public. If, however,

and handed down in January, 1909, gives emphasis to the need of practical recognition of depreciation by managers of public-service corporations, and will effectually estop hereafter any corporation from making claim for the effect of depreciation of its property that has failed to earn, through the agency of its rate, a sufficient fund to meet this depreciation.

Exception might be made in the plants which have not yet passed through the formative period, or which, by reason of heavy reconstruction expenses, have not been able to lay aside a suitable depreciation fund without increasing the rates. Such plants may have preferred to temporarily suspend the laying aside of a depreciation allowance, in the hope of making good the deficit a few years later, rather than to bear the public odium of temporary increase in rates. It seems reasonable to assume that a public-service commission would take the same view.

Without attempting a lengthy discussion of this subject, it may lead to clearness and be of service to lay down some of the principles which should govern us in making depreciation allowances in valuation, and which should have influence in the operation of a water-works plant.

DEFINITION AND KINDS OF DEPRECIATION.

Depreciation may be defined as the loss in value of a structure, resulting from wear and tear and other causes not covered by the repair and renewal accounts, or from loss in ability, with the lapse of time, to meet the demands of the service for which it was designed or to which it is being devoted.

Three broad classes of depreciation have been recognized:

1. Physical depreciation.
2. Functional depreciation.
3. Contingent depreciation.

Physical depreciation covers the deterioration of the structure through wear and tear, or similar causes, which result in its actual

a company fails to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over-issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purposes of earning a return cannot be enhanced by a consideration of the errors which have been committed in the past."

gradual inability to meet the required service, in spite of repairs and renewals from time to time.

Functional depreciation covers the loss in value, growing out of the necessity of abandoning the structure, on account of obsolescence, change in methods of operation, improvement of the art, increase in capacity of plant, or other similar causes.

Contingent depreciation should cover such loss in value of the structure as cannot logically be included in the other two items, and as shall make possible the gradual distribution, through a period of years, of any extraordinary depreciation item incurred in a single year, and thus have a steadying influence upon the financial operations of the company, relieving it of the burdens incident to the violent fluctuations in value which might result were such items charged directly to maintenance account. It is to be assumed, of course, that these items are properly chargeable to depreciation or maintenance, to the end that the capital investment may be unimpaired. Under this classification contingent depreciation may include such work as the cost of relocating the street mains, growing out of changes in grade or surface of the street by the municipality, the construction of subway or conduit systems by the municipality (in the case of telephone companies the placing of wires underground which had previously been overhead), and finally, as a matter of expediency, such major expenses as might otherwise be charged to maintenance account, — such as those growing out of serious losses from damage done by bursting mains, due to unforeseen and reasonably unpreventable conditions, — such as flaws in the material which cannot be determined by inspection; electrolysis by stray electric currents, et cetera. While it may be urged that such expenses should be charged to operation, — or better, maintenance, — we submit that such a course of procedure does injustice to the company through causing a false impression as to its financial ability to meet the losses, by seriously curtailing the annual earnings for the year during which the loss was incurred, when the distribution of the losses over a period of years, through the agency of such a contingent depreciation account, would show no marked affect upon the earnings and annual statement of the company. While, so far as the writer knows, this question has not been brought before the public

service commissions or the courts for adjudication, it seems probable that its soundness will be recognized by them and by all fair-minded men who have had business experience or experience in the operation of such works.

DIFFICULTIES OF OBTAINING RECORDS OF ACTUAL DEPRECIATION.

Specific information as to actual rates of depreciation is unfortunately limited, and attention is particularly called to a very common error in the interpretation of such data as are available, which a moment's reflection will make clear. From time to time, data have been published as to the length of life of certain engineering structures, — such, for instance, as pumps, — and it has been inferred from these data that the length of life of the average pump might be predicated directly upon them. Unfortunately, however, the data usually do not include a full history of the plants under investigation, but merely a record of the machines which have actually been thrown out of service, without consideration of the machines which are still in useful service. The effect of this is to substantially decrease the assumed period of useful life of the machine. Fortunately for the property holder, this error leads to a conservative assumption as to the period of useful life. Under these circumstances, it is clear that only breadth of experience with specific plants, or study of the actual experience of these plants, can develop competent judgment.

The actual rate of depreciation, in any given structure, may be exceedingly erratic. Take, for instance, the case of a pump in a water-works pumping station. A year after the new machine is installed, it is a better machine for the service than it was upon the day of its erection, for the reason that not only have flaws in construction been made good, but the actual wearing parts of the machine have come down to a good bearing, so that the machine, as a whole, operates with better economy than at the beginning of its life. The pump may continue to be substantially as valuable to the works for a considerable period of years, until it is outgrown in size and a new machine has to be added to take care of the increased service. This pump then becomes a spare machine, operated only at times of light load, and has suffered a marked depreciation in value because it will not meet all of the demands

of the service successfully, although it may assist in increasing the economy of operation of the station by making possible the shutting down of the new large or larger unit which had to be purchased, when the consumption is not sufficient to develop good economy in the large machine. The old pump may continue in service for many years, reaching a period when it is so small as to be of value only as one of several spare machines, when its value is very heavily depreciated.

It will thus be seen that it is practically impossible, as an accounting problem, to attempt to follow the life-history of the individual machines or structures making up the water-works plant, and, as a practical matter, it is sufficient if there is laid aside, annually, from the income from the rates, a fund which will make good, from year to year, the losses by depreciation, or which will, in other words, replace the old structures, as put out of service, without injury to the capital account. If the assumption as to the life of the plant as a whole is substantially correct, errors in assumption as to the useful life of its component parts are not so serious, though substantial accuracy is desirable for its effect upon rate making problems or considerations.

METHODS OF COMPUTING DEPRECIATION FUND.

Granting that the water works should lay aside an annual depreciation account which, with or without its accretions, — depending upon the method of raising and maintaining this fund, — will be sufficient to maintain in the hands of the corporation monies which will enable it to replace each component part of the plant at the end of its useful life, thus maintaining the investment unimpaired, " What method is the most satisfactory for accomplishing this end, — that is, for determining the annual sum which shall be contributed to the depreciation fund? "

Two general methods are in common use, — the so-called " sinking fund " method and the " straight line " method.

The *sinking-fund method*, as its name implies, consists in laying aside each year, during the period of life of the structure under question, a sum which with its annual accretions, compounded annually at an assumed rate of interest, will leave in hand, at the end of the useful life of the structure, a sum equal to its original cost less its scrap value.

Owing to the fact that the scrap value of the structure frequently is little more than sufficient to cover the cost of its removal, and that, in the case of a long-lived structure, the present worth of the scrap value would be exceedingly small, engineers have generally omitted the correction for the scrap value of the structure and have assumed, unless the life of the structure was comparatively short, that the scrap value was negligible. In the case of very short-lived structures, it is better that the cost of the structure should be charged off to operating expense, rather than to capital account with large annual allowance for depreciation.

The *straight-line method* consists in laying aside an annual sum proportioned to the length of useful life of the structure. Thus, if the life of the structure be assumed at 30 years, one thirtieth of the difference between the original cost of the structure and its final scrap value shall be contributed to the depreciation fund during the entire life of the structure. The corporation will thus have in hand, at the end of the 30-year period of life, a sum of money equal to the original cost of the structure.

Mention might also be made of what might be termed "the individual analysis method of computing depreciation," for use in cases where unusual local conditions or temporary circumstances might be dominating factors. As this method is rather in the nature of a modification of the other methods cited than a specific method of computing depreciation, no further comment is needed upon it.

Difference between These Methods.

The essential differences between these two methods of meeting the needs of the depreciation account are:

First, the fact that the *sinking-fund method* requires not only an annual contribution to the principal sum of the depreciation account, but that care be observed in the method of accounting for this fund, to the end that it may receive annual accretions of interest, which accretions with the principal sum and contributions will receive annual interest, so that the fund may, in fact, be a true sinking fund and enjoy the compounding effect of the interest allowances.

In the case of the *straight-line method*, no accretions or interest

allowances are credited to the fund, — the principal sum of the annual deposits being sufficient alone to make up the necessary depreciation fund at the end of the useful life of the structure. Such earnings, therefore, as may be enjoyed upon the straight-line depreciation account should be credited to the general operation of the works and not to the depreciation account itself, whereas the reverse is the case in the sinking fund method of application.

Second, and of perhaps greater importance to the operator of water works, — particularly of new works, — the sinking-fund method requires much smaller annual contributions to the depreciation account, and the accretions thereon amount to a much smaller sum, during the early years of the life of the plant, whereas in the later years the accretions become a very important element, rapidly swelling the amount of the fund. It will thus be seen that the works are relieved by this method, in the early years of the formative period, from a burden which might prove heavy for the corporation and the water takers to bear under the straight-line method.

CORRECTION OF ERRORS IN ASSUMPTION AS TO DEPRECIATION.

What, it may be asked, will be the result of errors in judgment in the determination of the useful life of the component parts of water works?

If the assumption as to this length of life is too great, obviously the depreciation fund will dwindle, and it will be necessary for the corporation to gradually increase the annual contributions until the fund is again in a normal condition. If, on the other hand, the assumption has been too large, the depreciation account will grow at too rapid a rate, when the annual rate of contribution should be somewhat reduced. It should be noted, however, that the life of any one, or, indeed, the life of several component parts of the structure, must not be taken as indicative of the assumptions as a whole, for the reason that we must, of necessity, deal with average rather than individual results. If, on the other hand, the structure under consideration is one of large value, and the assumptions have been erroneous, steps might well be taken to correct the error as soon as possible. Thus, if the life of a large and expensive pump should prove to be but three fourths of the assumed

life, and the straight-line method of depreciation fund contributions had been assumed, there would be in the hands of the corporation, at the end of the life of this pump, but three fourths of the original cost of the pump. The capital would thus be impaired to the extent of 25 per cent. of the cost of this machine, unless the difference be made good from the depreciation fund and steps be taken to increase the annual contributions thereto to offset this original error in assumption. As to the useful life of the pump, if we grant that the management used reasonable judgment in the purchase of this machine, the investor is entitled to have his capital kept inviolate, or unimpaired, even though the machine fail to serve its intended purpose for as long a number of years as expected.

REASONABLE ASSUMPTIONS AS TO PERIOD OF USEFUL LIFE OF STRUCTURE.

All of these methods are but aids to judgment. They must be applied with care and discretion, and with a clear conception of the extent and effect of the local influences or considerations. No subject in the engineering field requires larger experience or riper judgment.

While general limits for depreciation in water-works property, found under what might be considered normal conditions, may be indicated and are submitted herein, the fact that local conditions and limitations are likely to have substantial influence upon current depreciation in any specific plant must never be lost sight of.

In determining what constitutes a reasonable annual allowance for depreciation in the operation of any water works, we are dealing with conditions yet to be developed, requiring foresight as well as "hindsight." Hence the hazards and penalties of errors in judgment must be weighed.

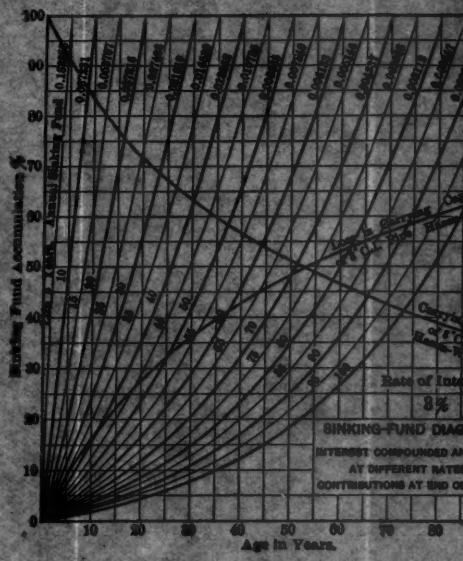
Final analysis of the necessary amount of or contributions to depreciation fund ultimately resolves itself into a question of expediency and standards of the day. It is well to be conservative in forecasting the annual needs for depreciation, alike in the interest of the public and of the corporation whose funds are invested in the plant; for it is easy to charge off or make future abatement for an excessive amount earned by the rates and credited to de-

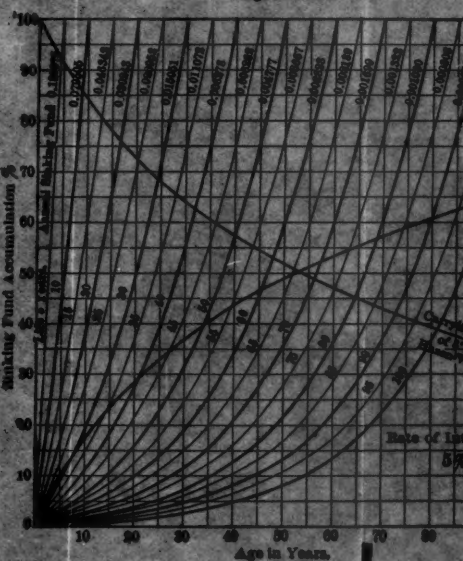
preciation account, while it may be difficult later to recover, by increased depreciation allowances, earlier deficits caused by failure to make adequate allowance therefor. In the long run, failure to make ample provision for depreciation, either through failure to earn it by the rates or to retain it in the treasury for legitimate corporate use (not for disbursement in dividends), must inevitably upon the one hand make capital apprehensive of the soundness of the management, if not of the project itself (and thus lead to demands for higher returns commensurate with the added risk, or to flat refusal to go into the project), and, upon the other, force the public to meet this demand by the payment of higher rates than would otherwise be necessary for the service rendered.

Cases sometimes arise in which the income of the water works may not at the moment justify what appears to be an adequate provision for possible or anticipated depreciation, and in which questions of expediency — growing out of the desire to avoid the public agitation and odium which would follow an attempt to increase rates for this reason — may make it preferable to take the chances of making good present deficiencies in depreciation account by future increments, rather than to raise the water rates temporarily. Such action may be justified *provided* the past financial history of the works indicates clearly that the growing net income will, with continuity of the existing water rates, in the *near* future produce a surplus which will wipe out this deficiency. This is particularly true of the allowance to be made for "contingent depreciation."

This condition corresponds to that of what might be termed the judiciously "over-built plant," which is at the end of a reformative period, so far as construction or reconstruction of the plant (that is, the physical plant) is concerned, and at the beginning of a recuperative period so far as the financial condition of the plant is concerned.

Similarly, it may be good judgment, if the water works have had an abnormally good business year, yielding an unexpectedly large net income, to credit a portion of this excess profit to depreciation account or to the amortization of the water-works debt, for the relief of subsequent bad years, as would be done under similar circumstances by the prudent manufacturer in running his busi-





Furnished through the courtesy of the American Society

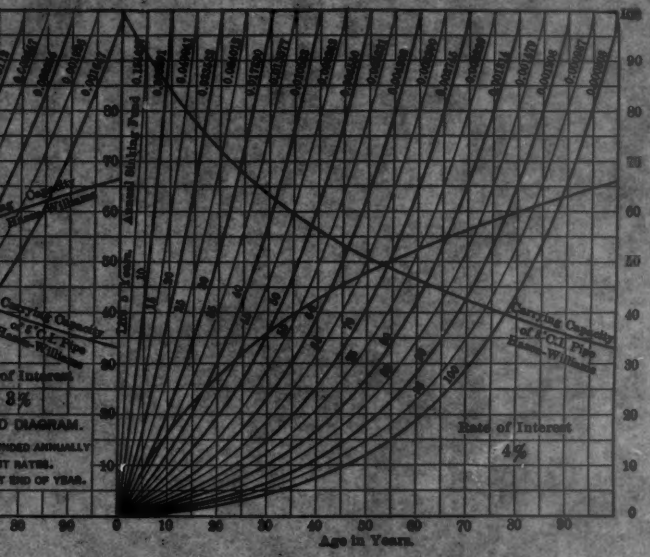
PLATE I.

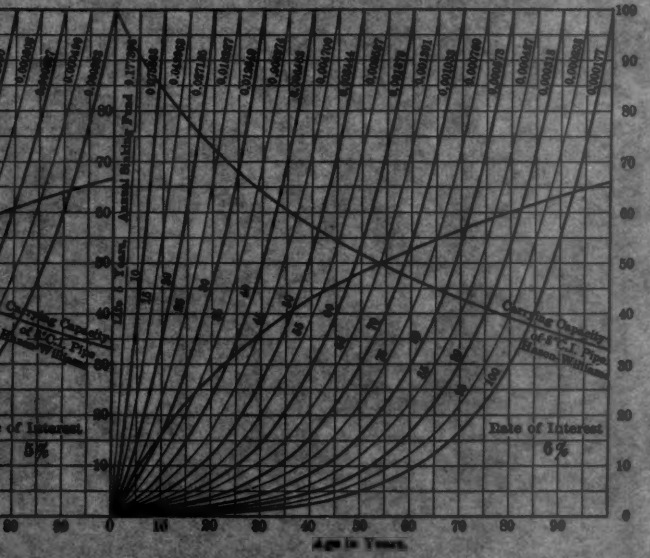
N. E. W. W. ASSOCIATION,

DECEMBER, 1910.

METCALF ON

WATER-WORKS DEPRECIATION.





Society of Civil Engineers, from Vol. LXIV, Metcalf on Water-Works Valuation.

ness. Nevertheless, Justice Moody's words, in his opinion in the Knoxville Water Company case, handed down by the United States Supreme Court in January, 1909, leave little room for the exercise of judgment in this annual provision of the necessary depreciation account allowances.

In the case of water-works valuation, the difficulty of determining the *accrued* depreciation, while substantial, is not so serious as is the difficulty of closely forecasting the *future* depreciation alluded to above.

Subject to the words of caution referred to above, the following approximate figures bearing upon the life of different structures entering into a water-works plant are given, as representing the general range ascribed to them by competent engineers testifying in water-works valuation suits. Knowing the period of useful life of a structure, the annual depreciation may be found by whatever method best fits the case. It will be well, however, to bear in mind the method to be used in figuring the depreciation, when estimating the probable life of the structure, if safe or conservative results are desired, — particularly if the sinking-fund method of computation is to be adopted and a high rate of interest is to be used in figuring the accretions upon the fund.

The following diagrams — Plate I based upon the sinking fund method and rates of interest of 3 per cent., 4 per cent., 5 per cent., and 6 per cent., and Fig. 1, based upon the sinking-fund method and rates of interest varying from $2\frac{1}{2}$ per cent. to 4 per cent., dependent upon the assumed length of life — will be found of service for rapid approximate computation or estimating purposes. Tables 2 and 3 also give similar data with greater precision. More complete information can be had from the " Robinsonian Bond and Investment Tables," published by J. Watts Robinson.

Data concerning formulæ for the computation of sinking funds, etc., are to be found in a paper presented by the writer before the American Society of Civil Engineers upon " Water-Works Valuation and Fair Rates," published in the Transactions of the Am. Soc. C. E., Vol. LXIV, 1909, pages 20 to 24.

An interesting article upon depreciation of contractor's plant was published in the issue of July 15, 1908, of *Engineering-Contracting*, in which are quoted the allowances made by MacArthur

Brothers' Company for depreciation upon their plant used in the construction of the Cross River dam for the Aqueduct Commission of New York City, the stated depreciations being monthly

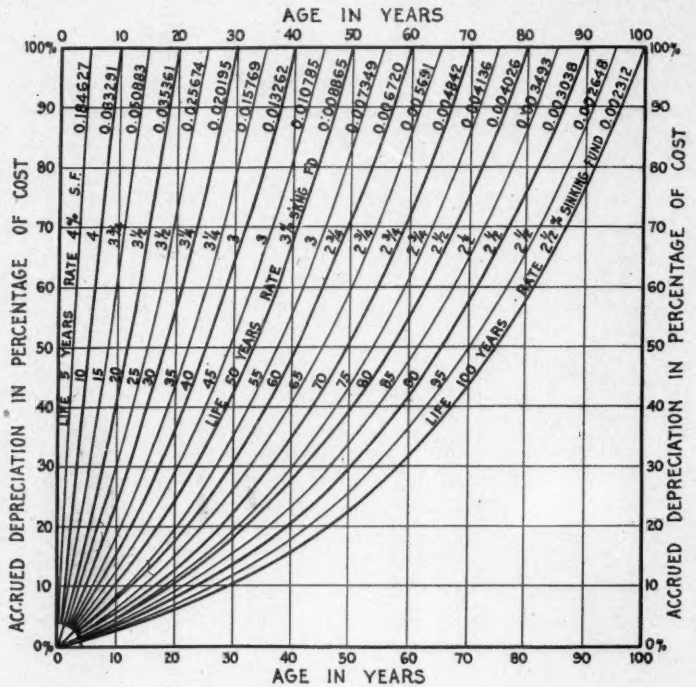


FIG. 1.

DEPRECIATION. DIAGRAM BASED ON SINKING FUND METHOD, WITH INTEREST RATES VARYING FROM 2½ PER CENT. TO 4 PER CENT., ACCORDING TO ASSUMED LIFE OF STRUCTURE. COMPOUNDED ANNUALLY, CONTRIBUTIONS AT END OF YEAR.

allowances. These data are submitted in Table 4, with a memorandum of the corresponding length of life, by the straight-line depreciation formula, and by the sinking-fund method, with 5 per cent. rate compounded semi-annually.

TABLE 1.

Approximate Life and Corresponding Annual Contributions to Sinking Fund.

Water-Works Structures.	General Limits of Useful Life, Years.	Corresponding Annual Contribution to Depreciation Account at End of Year in Per Centum of Cost of Structure,* based upon				
		Sinking-Fund Method, using Interest Rate Compounded Annually at				Straight-Line Method.
		5 Per Cent.	4 Per Cent.	3 Per Cent.	2½ Per Cent. to 4 Per Cent., Depending upon Length of Life.	
Reservoirs	50–100	½%–0%†	⅝%–⅛%	¾%–⅛%	0.89–0.23	2%–1%
Steel Standpipes	25–40	2⅛%–¾%	2⅜%–1%	2⅝%–1⅛%	2.57–1.33	4%–2½%
Masonry Buildings	30–50	1½%–½%	1⅝%–⅝%	2⅛%–⅞%	2.02–0.89	3⅓%–2%
Wooden Buildings	20–40	3%–¾%	3⅛%–1%	3⅜%–1⅛%	3.54–1.33	5%–2½%
Filter Plants, Permanent Construction	25–50	2⅛%–½%	2⅜%–⅝%	2⅝%–⅞%	2.57–0.89	4%–2%
Pumping Machinery, High Duty in large units	30–50	1½%–½%	1⅝%–⅝%	2⅛%–⅞%	2.02–0.89	3⅓%–2%
Ordinary Pumping Machinery	20–30	3%–1¼%	3⅛%–1⅜%	3⅜%–2⅛%	3.54–2.02	5%–3⅓%
Steam Engines	15–25	4⅜%–2⅛%	5%–2⅝%	5⅜%–2⅞%	5.09–2.57	6⅔%–4%
Boilers	12–20	6¼%–3%	6⅝%–3⅜%	7%–3¾%	6.66–3.54	8⅓%–5%
Electric Generators and Motors	20–30	3%–1¼%	3⅛%–1⅜%	3⅜%–2⅛%	3.54–2.02	5%–3⅓%
Masonry Conduits	50–100	¼%–0%†	⅝%–⅛%	⅛%–⅛%	0.89–0.23	2%–1%
Cast-Iron Pipe, large diameter.						
In Non-Tuberculating Waters	60–100	¼%–0%†	⅜%–⅛%	⅝%–⅛%	0.67–0.23	1⅔%–1%
In Tuberculating Waters	50–75	½%–⅛%	⅝%–¼%	⅞%–⅜%	0.89–0.41	2%–1¼%
Cast-Iron Pipe, small diameter	30–50	1½%–½%	1⅝%–⅝%	2⅛%–⅞%	2.02–0.89	3⅓%–2%
Steel Pipe	25–40	2⅛%–¾%	2⅜%–1%	2⅝%–1⅛%	2.57–1.33	4%–2½%
Wood Stave Pipe	20–30	3%–1½%	3⅜%–1⅝%	3¾%–2⅛%	3.54–2.02	5%–3⅓%
Wrought-Iron Service Pipes	15–30	4⅜%–1¾%	5%–1⅞%	5⅜%–2⅛%	5.09–2.02	6⅔%–3⅓%
Hydrants	35–50	1½%–½%	1⅝%–⅝%	1⅞%–¾%	1.58–0.89	3%–2%
Valves	40–50	¾%–½%	1%–⅝%	1⅛%–¾%	1.33–0.89	2½%–2%
Meters	15–25	4⅜%–2⅛%	5%–2⅝%	5⅜%–2¾%	5.09–2.57	6⅔%–4%

* By "Cost of Structure" is meant first cost of the physical structure, including allowance for "interest during construction" and "engineering and contingencies" items, but excluding "going value" and "franchise value."

† Less than ⅛ of 1 per cent.

TABLE 2.

Sinking-Fund Data.*

Life of Structure. Years.	Annual Contributions to Sinking Fund in Percentage of First Cost, with Different Assumed Interest Rates upon Sinking Fund Accumulations.					
	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Variable,† (4 Per Cent. to 2½ Per Cent.)	Straight-Line Method.
5	18.8355	18.4627	18.0975	17.7396	18.46	20.00
10	8.7231	8.3291	7.9505	7.5868	8.33	10.00
15	5.3767	4.9941	4.6342	4.2963	5.09	6.67
20	3.7216	3.3582	3.0243	2.7185	3.54	5.00
25	2.7428	2.4012	2.0952	1.8227	2.57	4.00
30	2.1019	1.7830	1.5051	1.2649	2.02	3.33
35	1.6539	1.3577	1.1072	0.8974	1.58	2.86
40	1.3262	1.0523	0.8278	0.6462	1.33	2.50
45	1.0785	0.8262	0.6262	0.4700	1.08	2.23
50	0.8865	0.6450	0.4777	0.3444	0.89	2.00
55	0.7349	0.5231	0.3667	0.2537	0.73	1.82
60	0.6133	0.4202	0.2828	0.1876	0.67	1.67
65	0.5146	0.3390	0.2189	0.1391	0.57	1.54
70	0.4337	0.2745	0.1699	0.1033	0.48	1.43
75	0.3668	0.2229	0.1322	0.0769	0.41	1.33
80	0.3112	0.1814	0.1030	0.0573	0.40	1.25
85	0.2647	0.1479	0.0803	0.0427	0.35	1.18
90	0.2256	0.1208	0.0627	0.0318	0.30	1.11
95	0.1926	0.0987	0.0490	0.0238	0.26	1.05
100	0.1647	0.0808	0.0383	0.0177	0.23	1.00

* Note. — Deposits at *end* of year, compounded *annually*.

† 4 Per Cent. Sinking Fund rate for 0 to 14 years life inclusive.

3¾ " " " " " " 15 to 19 " " "

3½ " " " " " " 20 to 25 " " "

3¼ " " " " " " 26 to 35 " " "

3 " " " " " " 36 to 55 " " "

2¾ " " " " " " 56 to 75 " " "

2½ " " " " " " 76 up.

TABLE 3.

Annual Contributions to Sinking Fund.	Approximate Age in Years at Maturity or End of Life of Structure, with Different Assumed Interest Rates upon Sinking-Fund Accumulations.					
In Per Cent.	3 Per Cent.	4 Per Cent.	5 Per Cent.	6 Per Cent.	Variable.* (2½ Per Cent. to 4 Per Cent.)	Straight-Line Method.
¼	87 years	72 years	62 years	55 years	97 years	400 years
⅜	74 "	63 "	55 "	49 "	83 "	267 "
½	66 "	56 "	49 "	44 "	69 "	200 "
⅝	59 "	51 "	45 "	41 "	62 "	160 "
¾	54 "	47 "	42 "	38 "	54 "	133 "
⅞	50 "	44 "	39 "	35 "	50 "	114 "
1	47 "	41 "	37 "	33 "	47 "	100 "
1¼	41 "	37 "	33 "	30 "	41 "	80 "
1½	37 "	33 "	30 "	28 "	37 "	67 "
1¾	34 "	30 "	28 "	26 "	34 "	57 "
2	31 "	28 "	26 "	24 "	30 "	50 "
2½	27 "	24 "	23 "	21 "	25 "	40 "
3	23 "	22 "	20 "	19 "	22 "	33 "
3½	21 "	19 "	18 "	17 "	20 "	28 "
4	19 "	17 "	17 "	16 "	18 "	25 "
5	16 "	15 "	14 "	14 "	15 "	20 "
6	14 "	13 "	12 "	12 "	13 "	17 "
7	12 "	12 "	11 "	11 "	12 "	14 "
8	11 "	10 "	10 "	10 "	11 "	12 "
9	10 "	9 "	9 "	9 "	10 "	11 "
10	9 "	9 "	8 "	8 "	9 "	10 "
15	6 "	6 "	6 "	6 "	6 "	7 "
20	5 "	5 "	5 "	5 "	5 "	5 "

*See note at foot of Table 2.

TABLE 4.

Plant.	Monthly Depreciation. Rate allowed by Contractors. Per Cent.	Corresponding Life in Years by Straight-Line Method.	Corresponding Life in Years by Sinking Fund Method. 5 Per Cent. Compounded Semi-annually.
Locomotives, cars, tracks, excavators, machinery, etc...	1.1	7.6	6.5
Scrapers, wagons, etc., horses, mules, etc., ...	2	4.2	$3\frac{5}{6}$
Camp equipment	2	4.2	$3\frac{5}{6}$
Small tools	5	$1\frac{2}{3}$	$1\frac{5}{6}$
Boats, scows, etc.	4	2.1	2.
Office furniture	1.1	7.6	6.5
Real estate	$\frac{1}{4}$	$16\frac{2}{3}$	$12\frac{1}{4}$

In this connection it may also be of interest to allude to the fact that Metcalf & Eddy, in reporting to the Boston Finance Commission in 1908 upon the cost of machinery and fair rental therefor, fixed, as an extreme monthly rental, 5 per cent. of the cost of the machinery, assuming that in the case of the larger machinery, which would be likely to have longer life, the rate should be correspondingly reduced.

The average length of life of water-works plants depends upon many factors. Broadly speaking, from 40 to 60 years probably represents the usual range of life of the structures, except in the case of very rapidly growing towns or cities.

The Wisconsin Public Service Commission, in a recent opinion upon the value of the Fond du Lac, Wis., water works,* gives the average life of the different water-works plants examined by it to date as $65\frac{1}{4}$ years.

The United States Commerce and Labor Bureau, in its Special Report upon "Statistics of Cities having a Population of over 30 000," in which are included some valuable water-works statistics, assumes a fifty-year period of life, corresponding to a 2 per cent. annual rate of depreciation upon the straight-line method of computation, but applies this to the present value of the plant. (If the going value and franchise value are *included* in the "present value of plant," this is more nearly equivalent to a 3 per cent. annual allowance for depreciation, based upon the repro-

* See page 275, *Engineering Record*, Vol. LXII, September 3, 1910.

duction cost upon which depreciation is usually figured, and would correspond in the above cited tables to an approximate period of life of 33 years, which is too short a life for average conditions.) Technically, the depreciation should be based upon the cost of the plant, though it may be applied as a per cent. of present value or gross annual income, for convenience, if errors of assumption be adjusted at intervals of 5 years more or less.

The total allowance to be made for depreciation, including contingent depreciation, will probably vary between limits of 1 per cent. and 2 per cent. per annum of the reproduction cost of the property, though in many cases it may lie even beyond these limits. Data are scarcely sufficient at the present time to fix the proper allowance for contingent depreciation with a reasonable degree of accuracy. It seems reasonable to anticipate, however, that an allowance of not less than one fourth of 1 per cent. per annum upon the sinking fund basis should be provided, and in many cases — perhaps in the majority of cases — this allowance will prove inadequate. In this connection it may be of interest to cite the experience of the Knoxville Water Company, the plant of which in a period of 17 years showed an average annual rate of depreciation, exclusive of proper allowance for repairs and renewals, of 2.12 per cent.

Owing to the variation in the amount of the gross income of water works, as compared with their cost or value, the depreciation thereon, expressed in percentage of the gross income, is correspondingly variable. Broadly speaking, however, it may be said that the depreciation is likely to amount to 10 per cent., more or less, of the gross annual income of the works.

Thus, if we assume a plant having a value of $5 000 000, a gross annual income of 10 per cent. thereof, or $500 000 per year, and a depreciation of 1 per cent. thereof, or $50 000 per year, the depreciation will amount to 10 per cent. of the gross annual income. Assuming value $500 000, gross annual income 12 per cent. equals $60 000, depreciation 1¼ per cent. equals $6 250, the depreciation would amount to *10.4 per cent.* of the gross annual income. Assuming value $50 000, gross annual income 16 per cent. equals $8 000, depreciation 1½ per cent. equals $750, the depreciation would amount to 9.4 per cent. of the gross annual income.

How many of you gentlemen, as water-works superintendents, are charging off 10 per cent. of your gross annual income to depreciation account, unless you are doing it through the agency of a sinking fund to retire the outstanding bonds upon your works?

RATES OF INTEREST TO BE ALLOWED UPON SINKING FUND DEPRECIATION ACCOUNTS.

In the straight-line method of computing annual depreciation allowances, no question of interest rate is involved, as the fund is not supposed to enjoy any accretions. Not so in the sinking-fund method, which is founded upon the assumption that the fund *shall* draw annual interest accretions. The interest rate to be allowed in figuring the annual accretions to the sinking fund of the depreciation account is, therefore, of prime importance, having substantial effect upon the annual contributions to the fund (in principal sum and accrued interest earned upon it).

In the eastern part of the United States two general theories have found application, first, that the depreciation sinking-fund allowance should be based upon a low rate of interest allowance, such as 4 per cent., commensurate with reasonable safety; second, that it should be based upon a 5 per cent. or higher rate, commensurate with the rate of interest paid upon the company's bonds or debt, upon the theory that the depreciation fund should be invested in the company's plant, or be applied to the retirement of its bonds or the amortization of its debt.

In the Middle West a theory was developed by Messrs. George H. Benzenberg and Benezette Williams, in the Sheboygan, Wis., water-works valuation suit, in the year 1900, and has since found application in the Omaha, Neb., Peoria, Ill., Des Moines, Ia., Flint, Mich., Mobile, Ala., and other cases, based upon a variable rate of interest (from $2\frac{1}{2}$ per cent. to 4 per cent.), dependent upon the assumed length of life of the structure,—the lower rate corresponding to the longer life. This theory has much to commend it, not only on account of its conservative effect, but because it gives practical recognition to the fact that the future is inherent with uncertainty and that the banker will be unwilling to allow as high a rate of interest upon a sinking fund of long life as upon one of short life for which future conditions can be more accurately forecasted.

RELATION BETWEEN INTEREST RATE AND HAZARD.

In the final analysis, however, it makes no difference which method is adopted, *provided* the plant be permitted to earn, through the agency of its rates, a profit upon its total value or property truly commensurate with the risks of the business, *including* in the latter a consideration of the provision for depreciation. If the depreciation allowances are too small, the risk of losses resulting therefrom is correspondingly increased and the plant must be allowed to earn a higher return or profit; if the depreciation allowances are evidently liberal, conservatively figured, the equitable return to be allowed upon the property is clearly smaller. The relative division of return from equitable rates between depreciation allowance and profit is at issue between the bondholder and the stockholder, rather than the consumer and the company, and the settlement of the question is reflected in the relative value of the bonds and the stock rather than in the rates.

RELATIVE DESIRABILITY OF THE SINKING FUND AND STRAIGHT-LINE METHOD OF FIGURING AND MAKING PROVISION FOR DEPRECIATION.

The sinking-fund method is believed to comport more closely with the life history of a water-works plant than the straight-line method. From the operator's point of view, it has the merit of smaller depreciation account requirements during the early years of the formative period when the new plant is acquiring its business, due to the compounding effect of the interest accumulations in the later years of the plant's life. From the consumer's or public point of view it has the advantage of tending to equalize rates during the life of the plant, decreasing the burden to be met by the rates in the early years of few consumers and increasing with the growth in demand for water.

From the accountant's point of view the straight-line method is much to be preferred on account of its greater simplicity in application and freedom from the necessity of accounting not only for the annual contributions to the principal of the sinking fund, but also for the accretions thereto to cover interest allowances. The corrections, from time to time, for errors in assumption as to depreciation allowances are also simplified.

On the other hand, the two methods are interchangeable or convertible, and the equivalent annual straight-line contribution for a period of 5 years, for instance, corresponding to the sinking-fund method requirements for a like period, may readily be figured and thereafter more easily be applied. As previously stated, it is desirable to check up the depreciation account allowances with the property valuation and to examine the fairness of the rates at intervals of not over 10, and preferably 5, years.

THE RELATIVE DESIRABILITY OF DISTRIBUTING THE DEPRECIATION ALLOWANCES AND CHARGING THEM OFF FROM THE SEVERAL ACCOUNTS INVOLVED OR OF CARRYING THEM IN ONE MAJOR ACCOUNT.

Whether it is preferable to distribute the depreciation allowances or carry them in one account will depend upon the bookkeeping methods employed and the conditions under which the works are operated.

One general account shows, at a glance, the adequacy of the provision made for depreciation. It may be a menace and object of unjust attack, however, at the hands of the political demagogue or inexperienced critic. With the public service commission in control, or a fair-minded public, no such result should follow.

The annual distribution of the depreciation allowance has, on the other hand, the advantage of making the several accounts show correctly upon their face the book value of each structure or group of structures and is preferable upon this account, though it makes the checking of the depreciation account more laborious.

DESIRABILITY OF SEGREGATING CONTINGENT DEPRECIATION FUND FROM PHYSICAL AND FUNCTIONAL DEPRECIATION FUND.

It is exceedingly desirable to account for the contingent depreciation fund separately from the physical and functional depreciation, not only that the necessary amount may be the more accurately determined, but that when this fund has reached what may appear, or later be determined to be, a reasonable amount, no further contributions should be made to it until substantial draft be made against it, reducing the remaining balance below a safe figure

or provision. The fund will, moreover, then be subject to annual review by the governing board of the works.

SINKING FUND AS A SUBSTITUTE FOR DEPRECIATION.

As a matter of fact, while few municipalities have recognized this depreciation, or perhaps even considered the underlying theory of it, they have, in effect, made allowance for it in the sinking-fund provisions of the bonded debt; and it may be added that the sinking-fund requirements have usually been in excess of the necessary allowance for depreciation, as a result of the assumption of a shorter life for the bonds than the actual life of the structures covered by them, though, perhaps, there is a tendency to-day to issue longer-term bonds, the terms of which in some cases exceed the probable life of the structure. This practice is to be condemned unless the sinking-fund requirements correct this evil; even then this practice appears illogical.

RENEWALS.

Engineers are somewhat divided in opinion as to the necessity of charging off to depreciation any portion of renewals involving a betterment of the service. Some contend that renewals involving betterments of service — there being no difference of opinion, of course, in regard to renewals which are mere replacements of existing structures — should be charged in part only to construction; or, in other words, that the value of the original structure not previously written off in depreciation should be deducted from the construction account simultaneously with the addition to it of the increment of value in the renewal represented by the betterment of the service; while other engineers contend that the entire cost of the element of the renewal representing the betterment of the service should be charged to construction account, without any deduction on account of the remaining value in the original structure which has been sacrificed or lost, upon the theory that the betterment is demanded by increased business or larger requirements, and that hence the new business should carry the entire burden of the larger debt thus created. To take a concrete example, let us suppose that the growing needs of a community necessitate the relaying of a 6-in. pipe with a 12-in. pipe. Upon

the first theory, the water-works company would be entitled to charge to construction account only the difference between the entire cost of the 12-in. pipe and the remaining value (i. e., not yet written off) in the 6-in. pipe, the rest being charged to renewals in offset to depreciation; upon the second theory, the entire cost of the 12-in. pipe might be charged to construction account upon the theory that the 6-in. pipe was still adequate to meet the requirements for which it was laid, and that the larger main was required by the greater demands of added business, which should, therefore, carry its entire cost. Furthermore, say exponents of the second theory, the saving in interest upon the smaller original structure during its life, as compared with the larger structure had it been built, has more than covered the cost of the smaller structure; to which it is replied that this fact has no significance beyond pointing the limits of rational design.

Certainly the first theory is the more conservative, and safer from the point of view of the bondholder or owner of the property.

PLEA FOR BETTER RECORDS.

In conclusion, the writer reiterates his plea to you superintendents of water works for more complete records of depreciation or life history of the different structures making up your own water-works plants. There is urgent need of them. Partial records, — that is, records of failure, — while of substantial value, are difficult of interpretation and often misleading in character. What we need is reliable records of the full history of your plants, the records of long life and useful service as well as of early failure or abandonment for special cause.

A committee of the American Water Works Association, of which the writer chances to be chairman at present, while Mr. John W. Alvord, of Chicago, the original chairman, is serving his term as president of that association, has already been at work upon this subject for nearly two years and has accumulated a considerable amount of data. It would welcome any further contributions which you may be willing to make to its investigation of this very important and interesting subject.

DISCUSSION.

MR. ARTHUR A. REIMER.* I should like to ask Mr. Metcalf whether any of the data on this subject accumulated by his committee indicate that the method of handling depreciation by a direct charge to the maintenance account has resulted in any heavy drains on the financial resources of the municipality or private company, so heavy as to cause inconvenience or demoralization. I ask this question because it is our practice not to consider depreciation as a separate account, but to handle all such charges through our maintenance account direct, and we have never been embarrassed in any way, nor inconvenienced, though we have had some heavy renewals and heavy replacements along with what might be called our normal maintenance expenses. We have never felt that it was at all out of the way for us to care for this depreciation item through our maintenance account.

MR. METCALF. I don't know that I can answer that question satisfactorily. I believe it is a fact that very few water works, whether publicly owned or privately owned, have made a practice of charging off depreciation as such. All works substantially have taken care of repairs and renewals through a maintenance account, or through an operating account, to a greater or less extent. Now if your provision in this particular case has been sufficient from year to year, or in the aggregate, to meet the actual depreciation in the plant, I cannot see that you would suffer any embarrassment by charging off a certain sum annually to a depreciation account and crediting it with the work which you had actually done. That is a mere matter of bookkeeping. If, on the other hand, your appropriations for this purpose have not been adequate and you were to make them adequate, it might embarrass you. I don't know what your gross income is, or what funds you have available.

In other words, as I understand it, you say in substance that you have merely taken care of renewals from time to time out of current income as an operating charge or as a maintenance charge or renewal charge, or whatever you may have called it. You have not charged it to new construction; you have not issued new capital against it. Now, if the renewals in the aggregate have

* Engineer and Superintendent Water Department, East Orange, N. J.

equaled the depreciation in the aggregate, your works have lost nothing, and the capital has not been impaired. If, on the other hand, the renewals are not equal to the actual depreciation, there will come a time when, unless you lay aside an additional fund between now and then, you will find your capital has been impaired.

Now, it seems to me that the only way in which you can tell whether the works are in sound condition is to have some means of following up your actual allowances for depreciation, with the actual records of the plant as to depreciation, in order to determine whether you are taking care of your capital, or have been dividing your capital in dividends, if you have paid any. That, it seems to me, is the thing which you have got to be exceedingly careful of, in the light of the Knoxville decision, because the Supreme Court virtually says to you that if you haven't to date taken care of the depreciation, you cannot collect it in the future. The sum which you have failed to collect is lost. As I have said, I think that the court would recognize the condition of a new plant, which had not had the opportunity to lay aside a fund, or, indeed, of an old plant which had just been put to the expense of reconstruction. I think some leeway would be granted there. Take the case of New York, which at the present time is putting millions of dollars into new construction, a lot of which is designed to meet future conditions. It would be unreasonable, in my judgment, to require them to earn, a year after that construction, a sufficient depreciation account to take care of it. In a period of years after that, however, they must do so; only it is less burdensome to the public, as I view it, to give them a longer period of years in which to distribute that depreciation allowance than to require them to take care of it at a certain specific rate beginning immediately after the new construction. The same thing happened in Cincinnati with its new construction work, and I might cite example after example.

In other words, almost all works go through certain phases. After the works are established and are under good operating conditions, the rates may be assumed to be adequate for the service which is being rendered. Gradually the service becomes incommensurate with the rates; I mean to say, perhaps the supply

is not as large as it should be, and the service does not meet the standards of the day. Then comes a period when the works earn really too much money on the service which they are furnishing; or, to put it another way, the service is not quite adequate. Then you come to a point where the company has to make large additional capital expenditures, and the works go again through a reconstruction period, as it were, when the rates are not adequate to the additional capital expenditures which have been made. But, taking a long period of years, the average may be all right. I think the court will recognize that. I think it would not be to the public's interest to demand that the rates should be changed from year to year; they must be settled for certain periods.

Now, trying to address myself to your problem directly, I do not think that as a matter of fact most water works have laid aside a depreciation fund as such. Many of them have had sinking funds to take care of their bonds, but, as I have said, in many of those cases the bonded debt is less to-day than the value of the works. In other words, they have done more than to take care of the depreciation in the plant. Others have not done that, and have suffered accordingly.

MR. REIMER. It was along the line of sinking-fund matters that I was thinking when I raised the point of treating depreciation through the maintenance account. Using as a basis the average life of the water bonds that have been put out by the majority of the municipalities or private companies during the past twenty-five or thirty years, if a properly figured sinking fund has been provided we find that the structures for which the bonds were issued have been paid for through the sinking fund well within the life of these structures. It is only within the past few years that we have a tendency to issue bonds of longer term than in previous years. I think you mentioned that fact and I think that you are right in the statement. This tendency will probably be more marked from now on, and is due to the fact, as I see it, that we have greater knowledge of the life of structures and perhaps a higher sense of responsibility in regard to financial matters. Certainly this is the case in the eastern part of the country. I am not familiar with western practice.

In regard to the question of charging a portion of renewals to the capital or permanent properties account, I feel that any department charging the entire cost of renewals to this account should be condemned. That portion of the cost of renewals which represents the actual increment of value is properly chargeable to the permanent properties account. I can see no good way of explaining why the entire cost of renewals or enlargements should be so charged. If we replace a 6-in. main with a 12-in. main and take out the 6-in. main, which often occurs, there certainly can be no question of adding to the permanent properties account only the increment of value due to the larger main. If, on the other hand, the 6-in. main be left in place, then I agree that the whole cost of the enlarged main is properly chargeable to the permanent properties account. This subject has been argued in my hearing by various men, and some of the arguments offered in favor of putting the entire value of the larger main into the permanent properties account where a smaller main is actually removed, using that as an illustration, are entirely fallacious, to my mind. The subject is one that is worthy of more thought and consideration on our part, and the work being done by Mr. Metcalf and his committee should be of large benefit to us in reaching a conclusion on these matters.

MR. METCALF. Answering your last statement, I think there is much to be said for your point of view. Of course the chief argument which the advocates of the theory which you are condemning bring forward is this: that the 6-in. pipe was put in, in the case you cite, when under the conditions an 8-in. pipe might have been put in; that they put in a smaller pipe with the idea of replacing it later, and that they have saved, therefore, in interest charges enough to make good that difference in cost. The argument does not appeal to me very strongly, but that is their ground for that view, I think. It lends color to it, at all events.

MR. THEODORE H. MCKENZIE.* Mr. President, there is one matter in connection with depreciation which it seems to me that Mr. Metcalf did not cover. Many of the water works in the eastern states are gravity works; I noticed that he did not mention the matter of depreciation of dams and reservoirs. For instance,

* Engineer Connecticut State Board of Health.

in the works with which I am connected the reservoirs cost fully 40 per cent. of the entire cost of the works. The water is impounded by earthen dams which are fully as good to-day as when they were built, twenty-seven years ago. The life of such reservoirs is almost indefinite; it ought to be considered as not less than one hundred years.

Another matter is the water rights; that is, the right to divert water from mill owners and from other users of water. For instance, water rights for the works with which I am connected were settled in 1883 for $5 000. In 1896 I had occasion for an adjoining city to settle similar water rights, and we were obliged to pay about $33 000 for about two thirds the area of shed settled for in 1883. The probabilities are that to-day the same water rights are worth much more than they were in 1896. Nearly all the water rights in that vicinity are taken up by some city, so that they must be considered of considerable value. The items of reservoirs and water diversion have increased in value more than the pipe system has depreciated.

Another matter which occurred to me: When many of the water works in the eastern states were built, from 1870 to 1890, pipe was worth $40 a ton, — in some places $42 to $45 a ton. To-day the cost of pipe is from $20 to $23 a ton, and there is not much probability of the price going higher. I do not know how Mr. Metcalf would consider the matter of depreciation with reference to pipe, which then cost $42 a ton and now is worth $22, whether he would provide a sinking fund to pay the cost of renewal of the pipe or to cover the original cost of the pipe, or what he would consider the depreciation or appreciation in the value of the water rights of dams and reservoirs.

Mr. James L. Tighe.* I would like to ask if any of the members here are aware of any municipality which has established a depreciation fund for taking care of these things.

The President. I think, Mr. Tighe, that there are a great many cities which have a sinking fund to provide for the payment of the bonds.

Mr. Tighe. I mean a sinking fund in connection with the depreciation.

* Engineer Water Works, Holyoke, Mass.

THE PRESIDENT. It amounts to the same thing.

MR. TIGHE. I do not think so, Mr. President, as a sinking fund formed for the payment of debts of no specified amounts, and anticipated only, must be different from a sinking fund formed for the payment of a specified debt already incurred, such as a bonded debt.

In the state of Massachusetts the legislature does not favor giving permission to borrow money now except on the serial bond basis, so that the old and very useful long-term sinking fund has practically been abolished in Massachusetts.

MR. EDWARD S. COLE.* It seems to me there is such a thing as depreciation by leakage. For example, in Chicago the Bureau of Water Surveys, which it was my pleasure to start some years ago, has recently reported, as the result of district measurements covering a considerable area of the city, that only one third of the total pumpage in Chicago is used by consumers, one third is wasted at leaky fixtures, and one third is lost underground. Such a distribution system has depreciated very greatly by reason of its excessive leakage and waste, thus increasing the cost of operation not only in pumping expense, but in interest account for extensions made necessary to maintain adequate service in spite of leakage.

When such a system is to be purchased by a municipality it would seem that its value as a revenue-producing property is somewhat impaired. It costs too much to buy and too much to operate.

In my own opinion, this depreciation by leakage is represented by far more than the cost of making the system reasonably tight, and the exact method by which it receives its proper allowance in the valuation of water-works plants should be carefully considered.

MR. WILLIAM F. SULLIVAN.† Mr. McKenzie spoke of the appreciation of water rights, of land values, and of the increment from other sources. This increased value of water rights with no monetary appreciation often becomes a burden on a water company with a fixed income, and as often a city or town exacts additional taxes for the increased valuation. My point is, that such

* Consulting Engineer, New York.

† Superintendent, Pennichuck Water Works, Nashua, N. H.

appreciation is not tangible, and money cannot be readily realized or obtained from such increase, and that you cannot from such increment lay water pipes, build dams, or install pumps, for the increased value is only on paper so far as a water works in concerned. Looking at appreciation from this point of view, it often is more of a liability than an asset, and does not always offset depreciation.

MR. EMIL KUICHLING.* Every private corporation that is about to be appraised for municipal ownership finds out that depreciation is a real and practical thing, and in most cases it becomes the cause of serious dispute. The representatives of the city usually call for a depreciation of much higher percentage than an expert would think of allowing. If one company is to be bought out by another, it also figures very seriously.

The great trouble is that we have so few reliable data. When called upon to exhibit the actual observations upon which we fix our rates of depreciation, the showing is generally unsatisfactory. Most of our data are of comparatively ancient origin, and are not based upon the apparatus and materials used at the present time. On searching the literature of the subject, it will be found that many of the figures are based on mere opinions, expressed many years ago before some commission or tribunal, and have been carried along by a variety of authors without any alterations founded on later experiences. This fact serves to emphasize Mr. Metcalf's strong appeal for a new set of figures. When these become available the subject will be on a much better basis than it is now.

A movement of this kind was started about twelve years ago in the American Water Works Association, and resulted in the publication of some valuable statistics about American pumping engines and boilers by Mr. John W. Alvord in 1903. It is to be hoped that this good work will soon be extended by the presentation of similar data, relating not only to pumping engines and boilers, but also to standpipes, reservoirs, conduits, distributing pipes, valves, hydrants, buildings, and all other details of a waterworks plant.

MR. MCKENZIE. I want to add one word with reference to

*Consulting Engineer, New York.

the methods considered by Mr. Metcalf, if applied to the valuation of a water works. A water works which has a good water supply has presumably been extended on the lines where the population has increased so that there is a large number of people, probably ten times the population that were on the lines of the system when it was first built; and that matter should be taken into consideration in estimating the value of the works. That is, if it is a good going concern, and has a good water supply fed by gravity, it should be considered with reference to its earning capacity as well as with reference to the depreciation of the plant.

The earning capacity of the works is a larger factor in determining the value of a water works than the actual cost price of reproducing the plant.

MR. METCALF. Mr. President, in answer to some of the questions which have been put to me, — I think I did refer to the depreciation allowance upon reservoirs, and put the life from fifty to one hundred years; and dams would, perhaps, come under the same general category. What Mr. McKenzie says about reservoirs I have no doubt is true. There is, however, this consideration which should not be overlooked, — that in the case of reservoirs functional depreciation may become an important element. That is, the growth of the community may require getting new sources of supply, which will make the old smaller sources of comparatively little value to the works. Under those circumstances I think he would agree that the reservoirs which he has to-day would have a less value to the works. If there is any fall in value through depreciation, then the cost, the capital, I submit, is entitled to be protected, and it should be taken care of through the agency of the rates, whatever method of accounting may be used, whether you take care of it through a sinking fund or a depreciation account.

Mr. Tighe has, I think, put the case clearly, and the President in answering him, that the majority of communities do not write off depreciation as such, but they have sinking funds for their bond issues, which more than take care of the depreciation. If you will examine the government statistics, which have been printed in the report to which I referred, in the years 1905, 1906, and 1907, which are now available, you will see that in a majority

of cases the value of the works as reported by them is probably considerably less than a true valuation of the plant. That simply means that the additional cost has been taken care of in the past through a sinking fund.

As to the question of water rights which Mr. McKenzie has raised, I think he has answered his own question. They appreciate generally rather than depreciate, consequently their writing off would be by way of lessening the depreciation allowance which must be made upon the entire plant. In a consideration of value, of course the water rights must be considered. I have not attempted to go into the question of valuation of works or the bearing of the depreciation question upon that value, because it is a very large subject, and it seemed to me that depreciation in itself was a large enough problem to present to you at this time. In general, and answering Mr. McKenzie's question, it seems to me that in the light of sound public policy the rates should take care of whatever loss in value there may be in any given period of years through depreciation. If the works have not earned it in the past, as I interpret the recent opinion of the Supreme Court of the United States in the Knoxville Water Company case, they cannot hope to earn it through the agency of rates in the future. Provision must be made for it substantially from year to year. But the opinion of the Supreme Court certainly does warrant their collecting an adequate fund in the future to take care of the depreciation.

Answering Mr. Cole's question, it seems to me that the subject relates rather to the operating expenses of the works than to any question of depreciation. As he has rightly said, the additional pumpage of water resulting from the leakage has served to swell the operating cost, and probably the maintenance cost, of the works. Now, it is to be assumed that the rates which have been earned in the past were predicated upon the existing conditions of operation, including these allowances. If in the future our standards of water-works practice should be raised, and money can be saved on that score, certainly it should be recognized in the rates. And in saying that I do not think that the company is entitled to the full enjoyment of saving in that direction. As to the effect of the fall in cast-iron pipe from $40 or $50 or $60 to

$25, again I would say that the capital invested in the plant at the time that cast-iron pipe was selling for $40 or $50 or $60 is entitled to protection, and if we see falling markets, if we know that the price of cast-iron pipe in any period of years is likely to decrease, we are justified in so proportioning the rates as to take care of that loss in value. It is only by doing that that you can get capital to go into projects of this sort, and it is for the public good that it should be done.

THE PRESIDENT. It seems to me that this is an oportune time to mention a conference which was held in Washington last May on uniform accounting for water works. At this conference, called by Dr. Powers, statistician of the census, there were present representatives from the American Water Works Association, the New England Water Works Association, the Certified Public Accountants Association, the Public Service Commission of Ohio, the Interstate Commerce Commission, and some other public commissions. There was drawn up a system to recommend for accounting by water works, and of course this question of depreciation was much discussed. This report, I think, will later be published by the census, in what form I cannot tell you, but I think it is to be published in serial form by the journal of which Mr. Muller, of the Interstate Commerce Commission, is editor. It is called *The Government Accountant*, and is published at 425–429 Bond Building, Washington, D. C. I think that those of you who are interested in this subject will find much there of interest.

MEMORANDA RELATIVE TO THE CITY OF ROCHESTER.

BY EDWIN A. FISHER, CITY ENGINEER, ROCHESTER, N. Y.

[*Read September 24, 1910.*]

The city of Rochester is situated in the county of Monroe, state of New York. The center of the city is about 7 miles south of Lake Ontario. The central portion of the city is about 260 feet above mean lake level and 510 feet above mean tide water.

The Genesee River flows through the city from south to north and has an aggregate fall of about 257 feet within the city limits. There are three principal falls within the city: the Upper Falls, of about 100 feet, near the New York Central & Hudson River Railroad; the Middle Falls, of about 25 feet, and the Lower Falls, near the northern portion of the city, of about 100 feet.

The Genesee River has a watershed of about 2 500 square miles. The flow ranges from a minimum, during the dry months, of from 150 to 200 second feet to a maximum flood of from 35 000 to 45 000 second feet. The water power of the river is utilized, very largely, by the Rochester Railway and Light Company.

The Erie Canal, passing through the city from west to east, was originally an important factor in its development. At the present time, however, the presence of the canal within the city limits has interfered with the development of certain portions of the city. The state is now constructing what is known as the "Barge Canal," which will take the place of the Erie Canal. Its location is about three miles south of the center of the city, passing through the Genesee Valley Park.

SEWERAGE.

We have within the city limits about 260 miles of sewers, all of them at present emptying into the Genesee River. Plans have been prepared, and are now before the state commissioner of health, providing for an intercepting sewer to take the sewage

out of the river to a purification station located near the shore of Lake Ontario and about two miles east of the Genesee River, where, after passing through the purification plant, the effluent will be discharged into Lake Ontario at a distance of about 7 000 feet from shore, into water 50 feet deep.

PAVEMENTS.

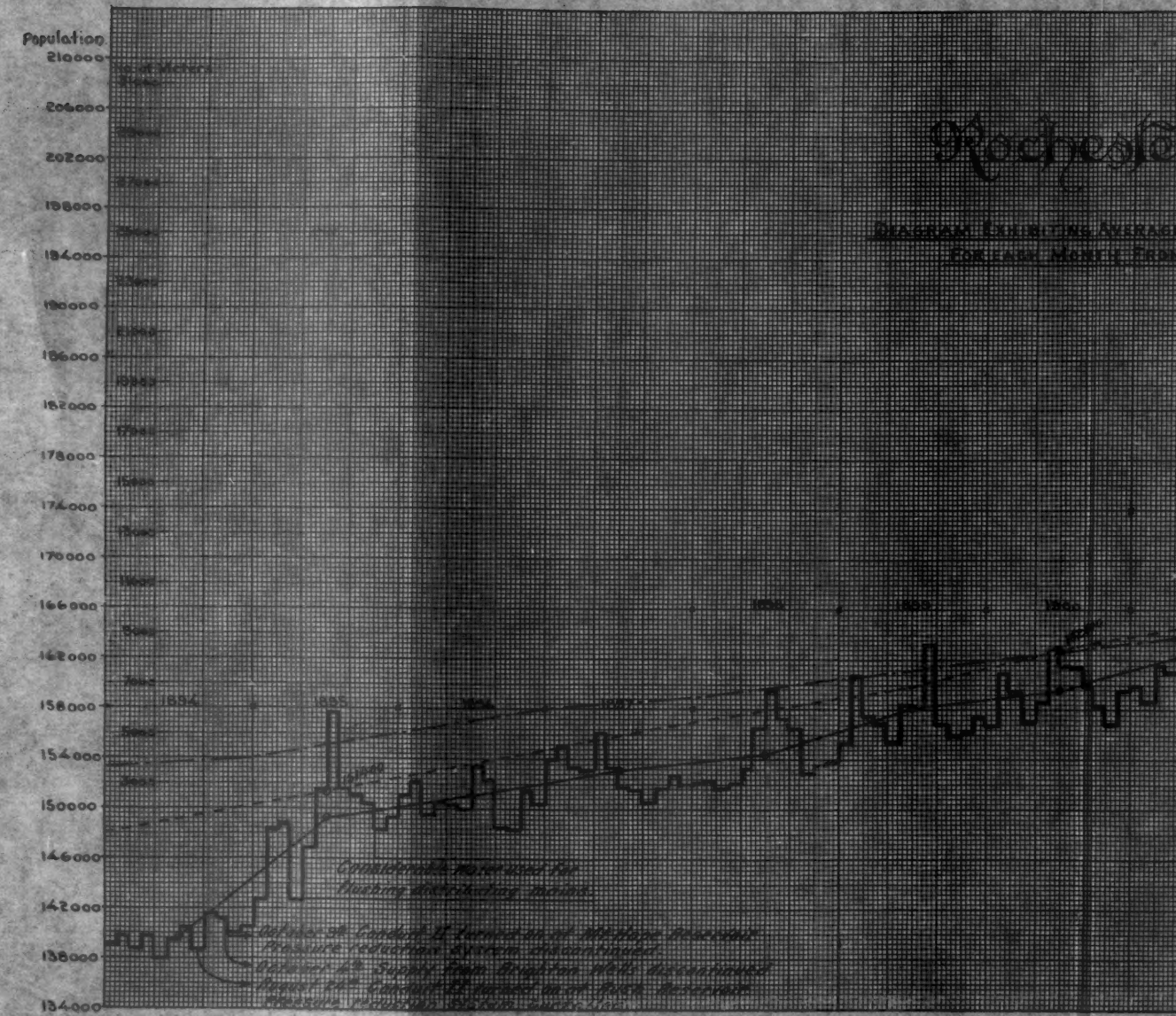
We have about 350 miles of streets, of which about 190 miles are improved as follows:

About 65 miles of asphalt,
15 miles of Medina block stone,
19 miles of common Medina stone,
45 miles of brick,
43 miles of macadam or gravel, and
3 miles of miscellaneous.

The pavements, sewers, and other similar improvements are constructed under what is known as "local improvement ordinances." These ordinances provide, generally, that the entire cost of the work shall be assessed, in the case of a pavement, upon the abutting property, and, in the case of a sewer, upon the drainage territory. This method of paying for such work is exactly the opposite of the practice in many New England cities where the entire cost of such work is defrayed from the general fund.

While our method, in many cases, imposes a hardship on the abutting property, it has resulted in increasing very largely the amount of improved streets over what there would have been had the opposite practice been followed. As a matter of fact, out of probably 150 ordinances for such work, adopted each year for several years past, we have had scarcely any objection from the property owners.

Another feature of our pavement work, in connection with water mains, is that in our main streets occupied by street railway tracks we lay two sets of pipes, one on each side of the street, so that the services do not pass under the railway tracks. In our investigations for electrolysis we have found no material damage by electrolysis to any of our water mains, but did find quite a number of cases of service pipes that had been damaged from that cause.


Population
210000
206000
202000
198000
194000
190000
186000
182000
178000
174000
170000
166000
162000
158000
154000
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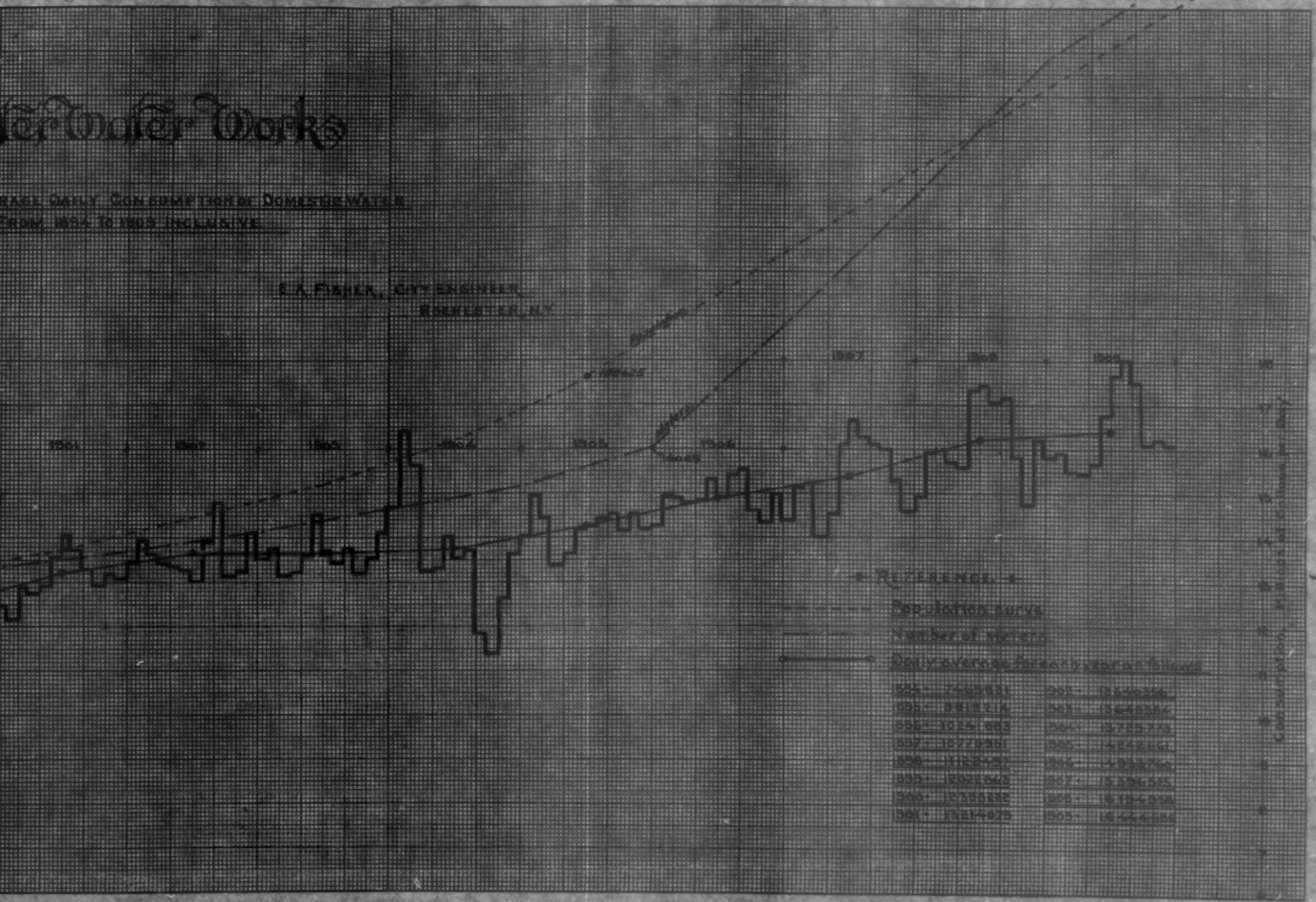
146000
142000
138000
134000
Rochest
DIAGRAM EXHIBITING AVERAG
FOR EVERY MONTH FRO
1894
1895
1896
1897
1898
1899

PLATE I.
N. E. W. W. ASSOCIATION,
DECEMBER, 1910.
FISHER ON
THE CITY OF ROCHESTER, N. Y.

...ter Water Works

...RAGE DAILY CONSUMPTION OF DOMESTIC WATER
...FROM 1854 TO 1909 INCLUSIVE.

E. A. FISHER, CITY ENGINEER,
ROCHESTER, N.Y.



STREET LIGHTING.

The city is lighted under contract with the Rochester Railway and Light Company. We had, on July 1, last, 3 761 arc lights and 312 tungsten lamps, making a total of 4 073 electric lights.

The spacing of the arc lights in the residence streets is generally 400 feet, unless, on account of intersecting streets, or for other reasons, this distance has to be modified. In the central portion of the city the spacing is very much closer, and in Main Street the average distance is about 80 feet. The appropriation for street lighting for the year 1910 was $239 000.

The arc lights connected with the overhead system cost $58.00 each, and, when connected with the underground system, $68.00 each, per year.

ELECTRIC SUBWAYS.

The Railway and Light Company has 71 miles of underground conduit, and the Bell Telephone Company has 60 miles. This amount of underground work is increased from year to year, and we expect in the near future that the main portion of the city will be entirely free from wooden poles and overhead wires.

This city has the reputation of being one of the best, if not the best, lighted city in the United States. It also has a reputation for the most extended use of electric power of any city.

It may be stated here, that the management of the Railway and Light Company, which owns and controls practically all of the electric and gas service in the city, is such as to commend itself to all our citizens, and also to serve as an object lesson to other municipalities in the manner of handling public service corporations.

PUBLIC MARKET.

This city is surrounded on the north and east by rich agricultural land devoted quite extensively to market gardening. During the season from 1 000 to 1 500 teams come into the city to sell and deliver garden truck.

Up to the year 1905 these gardeners used our own main public streets on the east side of the city during the night and early

morning. At that time the city purchased about ten acres of land and established a wholesale public market, affording accommodations for 1 200 teams within the market limits. The market has been successful from the start, and has proved a great convenience both to the market gardeners as well as to the city.

CONVENTION HALL.

Another branch of municipal work which has recently been taken up is providing a convention hall and an exposition hall for conventions and other public gatherings. The Convention Hall will seat about 3 800 people; and connected with it is the Exposition Hall, having about 3 600 feet of floor space.

The city has also recently acquired from the state a tract of land of about 42 acres, a portion of which will probably be devoted to the purposes of industrial expositions. This city has, through the activities of the Chamber of Commerce and the city officials, come to be recognized as one of the leading convention cities of the country.

WATER WORKS.

The present water-works system was constructed in the years 1873–74. Prior to that time extensive investigations had been made by several engineers as to the source of supply, and among those investigated were Lake Ontario, the Genesee River, and Hemlock Lake. It was decided to construct gravity works for a domestic supply, taking water from Hemlock Lake, — about 30 miles south of the city and about 390 feet above its general elevation, — and at the same time to construct an auxiliary fire service, taking water from the Genesee River.

So far as I know, this city was the first to establish a separate system of water works for fire protection, and this system at present covers more territory than any other in the country. The total length of pipe is about 20 miles. The capacity is at the rate of 13 million gallons per day. While it does not compare in working pressure to the few modern systems recently installed in some of the larger cities, yet it is, and has been from its inception, a very material addition to the efficiency of the fire department. The pressure during fires is maintained at 140 pounds.

The domestic system of water works covers the entire city, and consists of about 350 miles of pipe. There are about 4 000 hydrants connected with this system.

The area of the watershed of Hemlock Lake, and Canadice Lake and outlet tributary thereto, is about 66 square miles. The capacity is about 29 to 30 million gallons per day. The water is brought to the city in two gravity conduits, one completed in 1874, composed of 9.62 miles of 36-inch wrought-iron pipe, 3 miles of 24-inch wrought-iron pipe, and 15.5 miles of 24-inch cast-iron pipe. The wrought-iron pipe is made from $\frac{3}{16}$ inch- to $\frac{1}{4}$-inch plate. The capacity of this conduit is about 6.5 million gallons per day. A second conduit, completed in 1894, is composed of a 6-foot brick horseshoe-shaped tunnel 2.25 miles in length, and a 38-inch riveted steel pipe 26.19 miles in length. The steel pipe is made up of plates from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in thickness. The ultimate capacity of this pipe is about 16.5 million gallons.

It may be of interest here to refer to an official test made of the Holly, or Fire, System, on February 18, 1874.

A 2-inch stream was thrown vertically 210 feet, many feet above the top of the figure of the goddess of justice on the old Court House. A 3-inch vertical stream was thrown from a point near the corner of State and West Main streets 285 feet. A 4-inch vertical stream was thrown to an elevation of 294 feet. The same stream was thrown horizontally a distance of 365 feet. A 5-inch vertical stream was thrown to an elevation of 256 feet. These are some of the tests made, with reference to which the late Mr. J. Nelson Tubbs, then chief engineer of the water works, said, "It is believed that this was the most remarkable exhibition of large streams ever made in any country, and as such it attracted widespread attention from the hydraulic engineers, compelling the introduction of larger factors in the hydraulic formulas used to determine the results to be obtained from large streams with liberal size pumping mains."

Referring to the quality of the water of Hemlock Lake, the following quotation from an address before your Society* in June, 1887, by Prof. A. R. Leeds, Ph.D., of the Stevens Institute of Technology, may be of interest.

* Journal New England Water Works Association, Vol. II, page 79.

"It seems to me astonishing that at the present time, so far as I know, only two large cities in the country have water of unexceptionable quality. These I believe to be Brooklyn and Rochester. None of the others, taking them in their descending order, Washington, Baltimore, Philadelphia, New York, and so on down, none of the larger cities in this country, with the exception of the two I have mentioned, as far as I know, have water of unexceptionable quality."

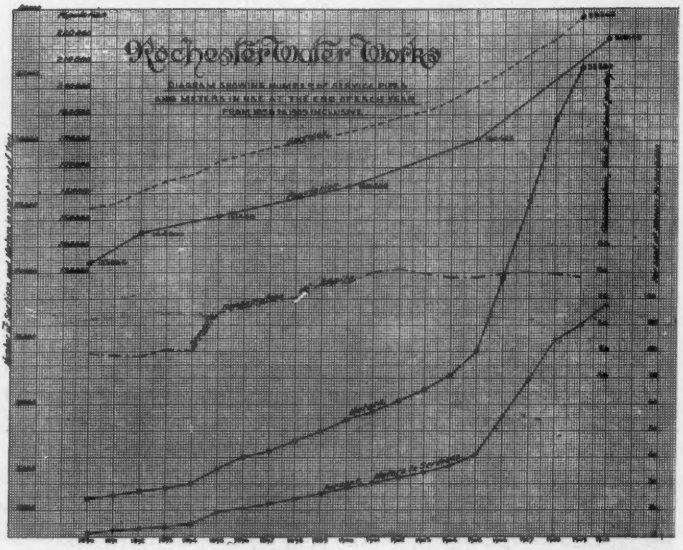


FIG. 1.

DIAGRAM SHOWING INCREASE IN POPULATION, NUMBER OF METERS AND SERVICES; AND CONSUMPTION.

Referring to Fig 1, showing increase in population, number of meters, and amount of water used, it is interesting to note that Mr. Tubbs, in referring to this matter in the year 1889, in a speech before the Common Council, said, with reference to a suggestion that a reduction in the amount of water used could be made by the wholesale introduction of meters: "It would require more than 19 000 of these to cover the services at present unmetered, and

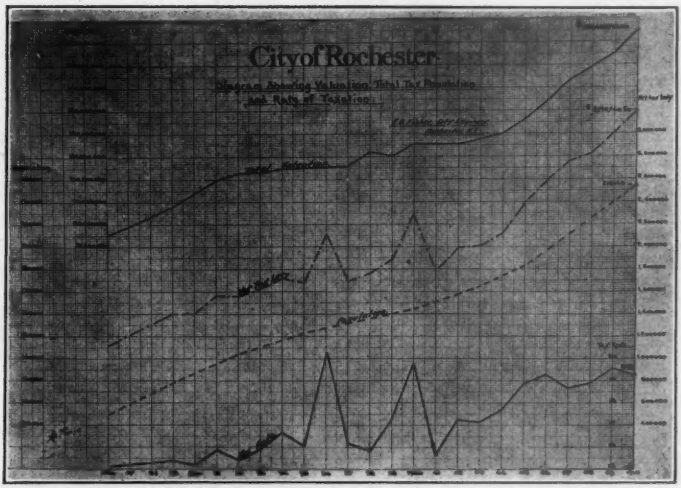


FIG. 1.
DIAGRAM SHOWING INCREASE IN POPULATION, TAX RATE, AND NET TAX LEVY.

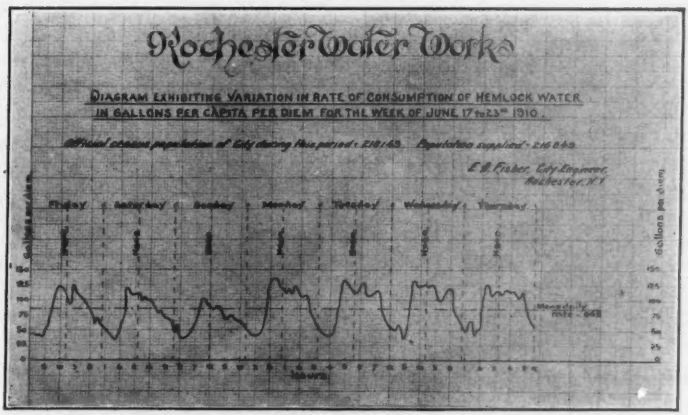


FIG. 2.
DIAGRAM SHOWING VARIATION IN RATE OF CONSUMPTION.

take at least three years' time; and when this was done the natural accretion of population would have taken all the water saved by the process." The diagram shows that this statement was actually borne out by facts from the year 1904 to date, when practically the entire city has been metered. The increase in population, and in use of water due to a larger population, has taken up all the water saved by the introduction of meters.

CITY GOVERNMENT.

At a meeting of what is known as the "City Lunch Club," Saturday noon, last, a gentleman from Buffalo talked on "Commission Government for the City of Buffalo." He said, among other things, that interest in a change of municipal government was general throughout the country.

This is neither the time nor the place to discuss any new method of municipal government, and anything that I may say is not intended to advocate any particular method, but to describe the system in operation in this city.

In the year 1900 this city came into what is known as "Second Class Cities," and a so-called uniform charter was adopted by the legislature for the cities of Rochester, Syracuse, Albany, and Troy.

By virtue of a constitutional amendment, adopted in 1907, this city came into what is known as "Cities of the First Class," and on January 1, 1908, a new charter applying only to this city went into effect. The special feature of this charter, as well as the charter for cities of the second class, is that it sharply divides the city government into branches, the legislative and the executive.

The legislative branch is composed of the Common Council, the members of which are elected from each of the 22 wards. The president of the Common Council is elected by the city at large. The Council has very large legislative powers, and it is not necessary for the city to ask for special legislation at Albany for any of the ordinary operations of the city government. The Council has power to issue bonds and notes for any improvement which it may authorize, limited only by the constitutional provision that the indebtedness shall not exceed ten per cent. of the assessed valuation. This body has no executive functions. The

mayor has veto power over the ordinances of the Common Council, but the charter contains the usual provision that ordinances may be passed over his veto by a two-thirds vote.

The executive branch of the city government is, in theory and in fact, controlled by the mayor. The mayor has the appointment, and without confirmation, of the corporation counsel and the city engineer, who, together with the president of the Common Council, the comptroller and the mayor as president, constitute what is known as the "Board of Estimate and Apportionment." This board fixes the number of employees in all departments and bureaus of the city, and also fixes the salaries of all officers and employees, except in a very few cases where the salary is fixed by the charter.

This board also prepares and submits to the Common Council an annual estimate of the expenses of the city for the current year. It also has other extensive powers, some of them in approval of acts of the Common Council.

A second board, called the "Board of Contract and Supply," is composed of the mayor, the commissioner of public works, appointed by the mayor, the corporation counsel, city engineer, and the comptroller, an elective officer. This board has the letting of all contracts for city work, excepting for schools and parks, whenever the work or material costs more than $250.00.

This board also approves of requisitions for work for all departments, except, as stated, for amounts less than $250.00.

The executive business of the city is subdivided into the following departments. The Department of Public Works: The commissioner of public works is the head of this department and appoints, to serve during his pleasure, a superintendent of public works, superintendent of streets, a sealer of weights and measures, and the numerous other officers and employees necessary to carry on the department. The Board of Estimate and Apportionment determines the number of employees and their salaries.

The Department of Public Safety: The commissioner of public safety is the head of this department, which includes the Police Bureau, the Fire Bureau, the Health Bureau, and the Bureau of Buildings. The commissioner appoints the heads of these bureaus, and has general control of their operations.

The corporation counsel, appointed by the mayor, has the

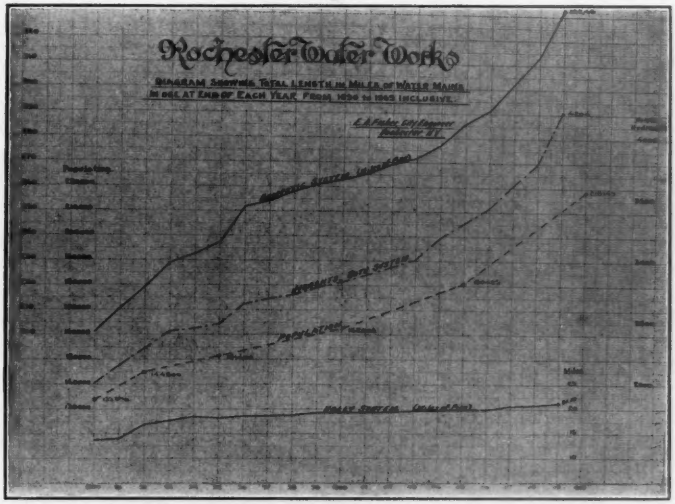

Rochester Water Works
Diagram Showing Total Length in Miles of Water Mains in use at End of Each Year from 1876 to 1905 Inclusive.
C. A. Fisher, City Engineer
Rochester, N. Y.
Number of Hydrants
Miles

FIG. 1.

DIAGRAM SHOWING MILES OF PIPE AND NUMBER OF HYDRANTS.

appointment of all of his subordinates, and has charge of all the legal business of the city, and, as before stated, is a member of the Board of Estimate and Apportionment and the Board of Contract and Supply.

The city engineer, also appointed by the mayor, has charge of all the engineering for the city, with the exception of parks and schools. He also is a member of the boards of Estimate and Apportionment and Contract and Supply, also of the Public Market Commission and of the Examining Board of Plumbers. He has charge of the maintenance of all city buildings, except school buildings and such as are used exclusively for the Department of Public Safety.

The heads of the various departments are appointed by the mayor at his pleasure, and without confirmation. The mayor, therefore, has absolute control over the executive departments of the city.

The mayor also appoints the park commissioners, who serve for a definite term. This Board of Park Commissioners has the supervision of the public parks. He also has the appointment of the Board of Examining Plumbers and of the market commissioners, and of quite a number of other minor officers.

Among the other elective officers is a board of four assessors which has charge of the general assessment of the city and also of special assessments for local improvements, or for other purposes.

The school board, consisting of five members, is also an elective board, and almost entirely exempt from control by any other branch of the city government, provided it does not ask for an appropriation exceeding $25.00 per capita of the registered pupils. For an appropriation exceeding that amount it is subject to the approval of the Board of Estimate and Apportionment and the Common Council.

There are also two municipal court judges elected, and one police court judge.

ROCHESTER PARKS.

BY C. C. LANEY, SUPERINTENDENT OF PARKS, ROCHESTER, N. Y.

[*Read September 21, 1910.*]

Rochester has five large parks: The Genesee Valley Park, situated on the upper river, contains about 500 acres, of which about 18 acres are devoted to golf, and about 10 or 12 acres to a polo and athletic ground; there are also a swimming pool, three baseball diamonds, seven tennis courts, two children's playgrounds, and a very beautiful grove in which there is a fine band stand, where during the summer there is music by the Rochester Park Band at least one day in the week. One prominent amusement is boating and canoeing on the upper Genesee, about twelve miles of the river being used for this purpose.

Highland Park, about 50 acres in area, was virtually given by the celebrated nurserymen, Elwanger & Barry. They first gave 20 acres and stipulated it should be devoted to an arboretum, and that some celebrated landscape gardener should be employed to make the design. The landscape gardener employed was Frederick Law Olmsted, the father of the Olmsted Brothers who are now employed by the city. He saw that the park was too small for an arboretum, and so he recommended a shrub collection and a pinetum. The shrub collection has been established, and every shrub that can be made to grow in this part of the country is growing in Highland Park. The pinetum is a collection of all the coniferous evergreens that will grow in this part of the country, taken from all parts of the world. A part of the shrub collection is a collection of lilacs, of which there are about 210 varieties, including all the different species and all the varieties that have been discovered so far. We also have a fine collection of hardy rhododendrons and the hybrid rhododendrons that are a cross between the American and those growing in Asia. We have also a collection of peonies, of about 210 varieties, not to mention quite a number that have not yet been named. All the shrubs are labeled with the common and with the scientific name. Besides

the peonies, we also have a collection of 27 varieties of magnolias, all the kinds that have been discovered so far that will grow in this climate. The southern magnolia, the magnolia that many southern people think is the only magnolia, is not hardy enough to grow as far north as Rochester. It grows as far north as Washington. Sometimes when our southern friends come up here and see the magnolias on Oxford Street they say, "Why, these are not magnolias," but when they see our collection they realize that there are other magnolias than the beautiful southern magnolia which they so greatly admire.

In Seneca Park, on the high banks of the Genesee River, we have about 140 acres of land. This park is planted mostly to the choicest of American trees. With very few exceptions there are no foreign trees in this park. There is a lake of 5 acres on which there are swan boats for carrying small children. In the winter this lake is kept clear of snow to allow skating. There is a small collection of animals, most of which are indigenous to this country. Many of the native birds and some foreign birds are in the aviary.

Maplewood Park was formerly a part of Seneca Park, and is on the left bank of the river. It was found inconvenient to manage the two parks on opposite sides of the river as one park, so they took the part of Seneca Park on the left bank of the river and called that Maplewood Park, naming it for the beautiful maple grove which is at the corner of Driving Park Avenue and Lake Avenue. At that corner we have established a rose garden in which are planted many of the choicest hardy roses.

At the lake we have Durand-Eastman Park, of about 500 acres. The land was given by Dr. Durand and George Eastman, of Eastman Kodak fame. The roads have been partly graded through the park. Recently a number of deer and a few other animals have been put into this park as an attraction. I think at the present time the people of Rochester do not fully appreciate this park, but at the rate that the city is growing now, in a very few years it will be found indispensable. A special feature of the park will be the facilities for bathing in Lake Ontario.

Besides the playgrounds in Genesee Valley Park, there is a children's playground at Maplewood Park, one at Seneca Park, one at Brown's Square, one of the most thickly populated parts of

the city; one at Thomas Street, and another at Hartford Street, both of which are in congested districts in which the children are mostly of poor parents. All the playgrounds are in charge of experienced instructors.

A children's pavilion was erected in Highland Park by Elwanger & Barry, at a cost of over seven thousand dollars, and dedicated to the children of Rochester in 1890. From this pavilion Lake Ontario, seven miles away, and the Bristol Hills, thirty-five miles away, may be seen on a clear day.

A RAMBLING DESCRIPTION OF THE ROCHESTER WATER WORKS.

BY BEEKMAN C. LITTLE, SUPERINTENDENT.

[*Read September 22, 1910.*]

Many times, while urging the members of this Association to visit us at Rochester, I have been met with the statement that we had nothing novel, intricate, or interesting in our water-works plant to show. My first feelings were of chagrin that such a complaint should be made, but these were quickly followed by feelings of pride, until second thought had to place such remarks under the heading "Important, if true."

Think of it! A water-works plant in its thirty-eighth year, so finely modeled years ago and so well managed since, that in its running nothing new is required and a humdrum existence is permitted its superintendent, whose gray matter is not disturbed by the solving of any problems! Two hundred and twenty thousand people served with water by some 38,000 service pipes and a like number of meters; 350 miles of sundry pipe, cast iron, wrought iron, steel, galvanized iron, black iron, lead and lead-lined, in sizes varying from ½ inch to 36 inches; two entirely separate and distinct systems of water pipe, one a high-pressure pumping system (the oldest in the country — used exclusively for fire protection, and the other a gravity system, used for domestic purposes as well as protection against fire. All of these, and yet nothing to interest a water-works engineer! It is too wonderful and good to be true.

In the thirty-eight years we *have* had to make changes and renewals of equipment, for old things *do* wear out, but credit should be given to some of those things that have stood the wear of time. We still have in use, regularly, the old Holly quadruplex steam pumping engine and the two water sets that were put in originally in 1872–3 for our high-pressure fire service, and I believe the chief engineer of the pumping station has an affection for these deeper even than he feels for the splendid new centrifugal pumps lately installed, one electrically driven and one operated by steam turbine, each of 3 million gallons capacity.

We have still doing service a number of our original hydrants. We are, to be sure, gradually taking them out, but not any more because they are worn out than because they are now too small to serve for the proper protection of the buildings and business houses which have grown up around them since they were installed, nearly forty years ago.

For the same reasons, large numbers of our valves and mains are being replaced, and yet many of these old mains and valves are found to be in good condition to-day. In particular, the cast-iron mains in our domestic system seem to be remarkably well preserved. In some cases there is almost no tubercular growth, and very little sediment is found. This fact, of course, is due probably more to our excellent water than to any virtue in the cast-iron pipes. In a number of localities on our high-pressure or Holly system, in place of removing mains and relaying larger ones, we have had the old mains cleaned, by contract. The work was satisfactory and the results very gratifying. This high-pressure system of pipes uses the Genesee River water, which is non-potable and exceedingly roily at times. In these pipes we find large deposits of silt and much tubercular growth after years of service. The cleaning machines remove them both equally well, with no bad after-effects that we have discovered.

While pleased with the results of our contract for pipe cleaning, I question the wisdom of the cleaning companies when they bid, as is their custom, — or at least was with us in our contract, — so much a foot for cleaning, regardless of whether the pipe is five feet underground or a foot and a half, as it may be in New Orleans; whether it is under a granite block pavement or in a dirt road; whether there may be service taps of various sizes every 20 feet to look after, or none at all, as in our high-pressure system; whether the machine may have a clear haul of 1 000 feet, or a cut in the main and pavement has to be made every 200 or 300 feet. I should certainly say that the prices for pipe-cleaning contracts should be determined by considering local conditions in each case.

In addition to the old mains and valves and hydrants which we are still using with good satisfaction, we have water passing through a number of old meters that were installed about thirty

years ago. The conclusion may be reached in time that there is practically no limit to the life of a meter, any more than there is to the life of a good watch, if it is taken care of and parts repaired or renewed as occasion requires. There is no reliable answer to the question, "How long will a meter last before it wears out?" As to how long it will register accurately without attention, that is another matter. We find that with our exceptional water, which is free from grit and has a uniform pressure, the disk meters are apt to register closer after long use than the piston or current types. This may not obtain in other places, where conditions are different.

To the writer, the behavior of our disk meters is remarkable. In 1905 we had fifteen $\frac{5}{8}$-inch disk meters removed for test, from residences which they had served for seven years. There were five meters, each from the three different manufacturers from whom we had been purchasing. The meters had all been set in service the same month of the same year and, seven years later, were removed and tested within a month of each other. The locations were selected at random and there was nothing unusual about the care which they had received from the householders. These fifteen meters were brought to the shop and tested without being cleaned or repaired in any way. On full-flow test, every single one registered within 2 per cent. of perfect. On the leakage test, with a $3\frac{1}{2}$-inch stream, eleven of them registered within 5 per cent. of perfect, or better; one of the remainder registered 9 per cent. in favor of the consumer, one 22 per cent., and two would not register until the stream was increased somewhat. The registration of the meters for the seven years varied from 18 000 cubic feet — or 2 500 cubic feet a year — to 86 000 cubic feet, or 12 300 cubic feet a year. This highest registration meant a water bill of about $13.00. Although all of these meters were set back in service, some without being taken apart and cleaned even, the only repairing made in order to have each one register perfectly before the resetting was to one disk, which had to be refitted.

This test was made in order to find out which of the three makes was giving the best satisfaction, and, to our great satisfaction, it was found that all three were best. Three one-inch disk meters

were also tested, which had been in service four years each. Two of these registered within 2 per cent. of perfect on both full stream and leakage test, and the other registered 3.7 per cent. on full flow and 17 per cent. on the leakage test in favor of the consumer. These meters had each registered an average of about 75 000 cubic feet a year.

These tests satisfied the writer that in Rochester, at least, it would not pay to remove all meters frequently for test, in order to save money, on the theory that the meters would under-register after several years' usage. That is, if the total amount of the water bills represented by the registration of these meters were increased by the per cent. which the meters were found to under-register, the difference would not be sufficient to pay for the trouble and time spent in testing the meters. These tests that have been enumerated were, as stated, made five years ago, after seven years' use. These meters were again removed last July, after twelve years' service. All but two registered within 2 per cent. of perfect on full flow, these two being 5 per cent. and 6 per cent. out of the way, respectively. On a very small leakage test, three would not register and the rest averaged 5½ per cent. out of the way. Of course, after these tests were made, each meter was cleaned, all necessary repairs made, and each was set back only after it registered perfectly on both full stream and leakage.

The older meters which we have in use are of the rotary piston type. Recently eight of the oldest ones, of ⅝-inch size, were removed. These were set in 1880 and 1881, twenty-nine and thirty years ago. Before cleaning or repairing, they averaged for accuracy less than 4 per cent. out of the way, on full flow, and about 11 per cent. on leakage test. These, of course, have been repaired or removed perhaps a number of times in the thirty years of use, but my point is that they are still in use and giving good service.

The use of meters in Rochester, now 98 per cent. metered, has undoubtedly kept our consumption down below what it would otherwise have been. While this does not mean saving in dollars for coal and extra pumping engines, ours being a gravity supply, it does mean that we have put off for a number of years the great expense of another conduit line and saved the interest on such a large investment. Long before this, without meters, we would

have exhausted the capacity of our present conduits. Of the larger cities of this country, there are few, if any, that have a smaller daily per capita or per service consumption than Rochester.

Practically all of our small services are of 3-A lead from the main to the curb. The plumbers lay them, under our supervision, after we have put in the corporation cock, and then the services are maintained at our expense. We suffer very little from electrolysis. The conditions here have been exceedingly good in this respect since the street railway company bonded all of its joints by electrical welding, and the company now makes frequent tests of its trackage system to see if the return is in good condition.

Our street mains are cast iron and our policy on the domestic system is not to lay any smaller that eight inches. Some 6-inch mains are laid, but only on cross streets, where the system is well gridironed. We install valves in abundance, and thus avoid the necessity of shutting off large sections in cases of leaks or breaks. Nearly all hydrant branches have valves; they are 6-inch, with some few 8-inch branches for the extra large hydrants. The small mains (especially 4-inch), laid years ago, are being replaced rapidly by the larger sizes.

On our high-pressure or Holly System we are, in our new work, installing nothing smaller than 12-inch mains. We allow private fire services, for standpipes, automatic sprinklers, and yard hydrants, to be taken from either our Holly system or the domestic system, but not from both. That is, the sprinkler equipment in a building cannot be connected up with a service from each system, even with a check valve between. The river water which we pump directly into our Holly system is so polluted that it would be a great menace to health to trust a check valve to keep the two supplies separate. Insurance underwriters do not like this rule, but have to put up with it.

On several of these private fire services, where there are yard hydrants, we have installed detector meters, and we intend to have them all metered eventually. On an ordinary service, the consumer pays for the meter, but on private fire services we have adopted the plan of furnishing the meter free, unless, or until, it is found that the water is used for other purposes than for extinguishing fires. In such cases we insist on the property owner

paying for the cost of the meter and the installation, as well as for all water used

We have two gravity conduits leading from our source of domestic supply, 30 miles away. The older one, laid thirty-six years ago, has caused, all told, but little trouble, either in the 14 miles of wrought-iron main or the 16 miles of cast-iron pipe of which it is composed. The second conduit consists of 38-inch steel riveted pipe, varying in thickness from $\frac{1}{4}$ to $\frac{3}{8}$ inch. This was laid sixteen years ago, and we have had considerable trouble with pitting on this conduit. For the past eight years we have, each summer, uncovered varying lengths and carefully scraped the old coating off and repainted the pipe with two coats of mineral rubber and two coats of graphite paint. On the sections thus recoated, we have had no further leaks and the pitting has not advanced appreciably. The probability is that the entire length of this steel pipe will eventually have to be thus treated. The pits or holes which occur, causing the leaks, are small and do not necessitate shutting off the conduit in order to make repairs. A wooden plug is pressed into the hole, a patch of lead placed over it, and over that is placed a square steel patch $\frac{3}{8}$ inch thick. Then this is all held in place, close against the pipe, by two half circles of wrought iron placed around the pipe and drawn tightly together by bolts.

From our source of supply, Hemlock Lake, which is seven miles long and half a mile wide, these two conduits lead first into a small storage reservoir about ten miles south of the city, and then from there down to the two distributing reservoirs on the southern boundary of Rochester. The purity of the supply is very well insured, as the city owns practically the entire shore of the lake, leaving but a few cottages on its entire 15 miles of shore-line. These cottages and residences are watched and inspected by water-works employees, and the garbage, etc, removed and buried off the watershed as often as necessary. The entire watershed of the lake is kept track of. The population of the 48 square miles is very small, and all cases of disease are reported, and any that may have possibilities of danger to our water supply are investigated and taken care of, if necessary. There is a small town of 600 inhabitants three miles south of Hemlock Lake, and,

while it is situated on the watershed, with the drainage all toward the lake, we have never had any bad results shown in our water supply. Conditions in this village are particularly watched by an inspector who resides there nearly all of the year and reports to the superintendent every week.

Only once in the last fourteen years since we started taking regular weekly bacteriological and chemical observations has the bacillus colon appeared in our water supply, and never has there been a case of typhoid fever in Rochester which has been traced to our water supply. Throughout the entire year of 1909 there were only 17 deaths from typhoid fever, or only one to every 12 000 people, and the average yearly rate for the past ten years has been only one death to about every 7 500 inhabitants. No other of the larger cities of New York state has a record like this. In fact, the only place at all which equals it is Yonkers, with a population only one third as large. It has been pretty well determined that all of the typhoid that we have had is contracted outside of the city. For instance, last year 70 per cent. of the typhoid cases were reported in September and the following months, after vacationists and excursionists returned from summer trips to places where Hemlock water was not available.

We have been troubled with algæ, and as far back as 1876 fishy flavor and odor were complained of. While the trouble has been with us more or less through all these years, it was not until the present year when it was long continued that active measures were taken to abate the nuisance. We dosed our largest reservoir with copper sulphate, after locating the trouble there and cutting off the reservoir from the rest of the distribution. This was done last May, and our trouble vanished quickly and we have had no complaint since. The treatment was found to be so simple in application and so efficacious in results that hereafter it will be tried on much less provocation than caused its trial this year.

Except for this one trial treatment of copper sulphate, our domestic water has never been doctored in any way, nor does it undergo any filtration whatever. We believe that it well deserves the place it occupies in the very front rank of the domestic waters of the country, if not of the world.

PERTINENT MATTERS RELATING TO THE ROCHESTER WATER WORKS.

BY FREDERICK T. ELWOOD, COMMISSIONER OF PUBLIC WORKS, ROCHESTER, N. Y.

[*Read September 24, 1910.*]

In connection with pertinent matters relating to water works, I thought it might be interesting, before the able papers on the various details, to give you a very brief talk on the evolution of the Rochester Water Works.

Early in the experience of every hamlet and village arises the need of a water supply for the protection of property against destruction by fire. At a later time, when the population becomes greater and the habitations more dense, with the consequent contamination of the soil, comes the necessity for a supply of water for domestic purposes other than the primitive wells.

From the earliest times the bucket brigade has been the first method adopted by a village to fight a fire, to develop with the growth of the village, through the different stages of fire apparatus, to a modern equipment. Rochester was not an exception to the rule, and her first bucket brigades dipped water from the Genesee River or pumped it from nearby wells until 1824, when the completion of the Erie Canal furnished a new source of supply. Later, reservoirs were built under the streets to supply the hand engines, but it was not until 1874 that the first stream was turned on from a hydrant. It must not be thought, however, that the question of water works had been sleeping during these fifty years. As the city grew, the natural supply became insufficient for protection, the wells were contaminated, and the water unfit for use for domestic purposes; there was much discussion and much demand for an adequate service.

In 1835 the legislature granted a charter to the first Rochester Water-Works Company, a private corporation, with a capital of $10 000. History does not reveal that this company accomplished

more than to effect its organization. In 1852 another company was chartered under the same name, authorized to expend the proceeds of $800 000 in bonds and $800 000 in stock. This company proposed to take water from Honeoye Creek, the outlet of Honeoye, Canadice, and Hemlock lakes, at Smithtown, sixteen and one-quarter miles from the city, conducting it by gravity to the distributing pipes by means of a 24-inch wooden conduit. In 1871 the company had finished its conduit, had partially completed a storage reservoir of 70 million gallons capacity about ten miles from the city and a small reservoir near the city, and had laid thirteen and one-half miles of distributing pipe. It was then found by test and examination that the wooden conduit could not be relied on, that the leakage was so great at the depressions that only a small percentage of water passed over the adjoining elevations, and that the amount reaching the distributing system was almost infinitesimal. The company had expended all its funds, but was reorganized and offered to replace the wooden conduit with iron pipe in consideration of a rather heavy yearly rental; but the people had become discouraged and suspicious of private water companies, so in 1872 the legislature created a board of water commissioners and authorized the city to construct and operate its own water system. The city finally purchased for $26 000 the distributing system and some land at Hemlock Lake from the old company. The uncompleted storage reservoir on the Henrietta road still remains as its monument.

Immediately on the appointment of the board of water commissioners the planning and construction of our present system was begun. It is not within the province of this paper to go into any detail, but simply to relate in a general way what has been accomplished. The plan adopted after much discussion was to construct a double system: a pumping plant, taking water from the Genesee River and using its own separate distributing system, for fire protection, and a gravity system for domestic purposes, taking water from Hemlock Lake in Livingston County, twenty-eight miles to the south of the city and at an elevation of 388 feet above the Erie Canal Aqueduct. The lake is a little less than seven miles in length and has an average width of three fifths of a mile. It is situated in a deep narrow valley in a sparsely settled district,

almost entirely surrounded by high bluffs. Its beaches are of shale; its water mostly supplied by springs. It has a surface area of 1 828 acres and a drainage area of 43 square miles.

The pumping system, with a daily capacity of 7 million gallons, was completed in February, 1874, and the tests were eminently satisfactory; in fact, they attracted, at the time, the attention of hydraulic engineers throughout the country. The greater part of the original machinery is still in use and, with its later additions, is furnishing, besides fire protection, power for hydraulic elevators and lift bridges

The conduit from Hemlock Lake was completed in January, 1876, and on the 23d of that month Hemlock water was flowing under the streets of Rochester, two years and eight months after the first pick was struck into the ground. The conduit commences in Hemlock Lake, 1 000 feet from shore, where the mouth is in thirty feet of water, and, after passing through the gate house, passes over hills and across valleys, through fields and along roads, to Rush Reservoir, about 20 miles from the lake. The bottom of this reservoir has an elevation of 224 feet above the Erie Canal Aqueduct; it has a capacity of 70 million gallons. Outside the reservoir is a by-pass by means of which the direct pressure from the lake may be thrown into the city. From Rush the conduit follows mainly along the highway to Highland and Cobb's Hill reservoirs on the outskirts of the city. This conduit furnished an unlimited supply of water until 1885, when, so rapid had been the growth of the city, the conduit was being used to its full capacity. Steps were immediately taken to procure an additional supply, and the construction of a second conduit to Hemlock Lake was finally decided on. During the next few years the water was husbanded with great care, but despite the precautions, the city narrowly escaped a water famine in 1888; a temporary supply became necessary and this was procured from artesian wells furnishing about 500 000 gallons daily.

The second conduit with a capacity of 15 million gallons was completed in 1894. This conduit commences 1 600 feet from shore at a depth of 35 feet. The first two miles is of brick tunnel 6 feet in diameter, protected from damage by pressure by an overflow chamber. From this point it is of 38-inch steel pipe, extending

over practically the same route to the same reservoirs as the old conduit.

These two conduits are now furnishing to the city an unstinted supply of the purest water of any city in the country. The conduits are supplemented by a storage reservoir at Rush, with a capacity of 70 million gallons, a distributing reservoir at Highland Park with a capacity of 25 million gallons, and our lately completed Cobb's Hill Reservoir with a capacity of 140 million gallons.

And now a word as to why our water is so pure. Hemlock Lake, with its high, thickly wooded ridges, is one of the most beautiful lakes in the country. Its beauty naturally attracted the summer cottager, and, in the early days of its use as a water supply, its shores were liberally sprinkled with cottages. During this time a strict patrol of the lake was maintained, the beaches kept cleaned and all foul matter collected in pails and buried outside the watershed. Gradually the city has acquired by purchase a strip 200 feet wide along almost the entire shore line, the cottages have been removed and the shores are slowly returning to their primitive state. The patrol is still maintained, but its work is comparatively light.

Canadice Lake, which lies less than two miles from Hemlock Lake and parallel to it, will soon be used as an additional source of supply. This lake is similar in its natural surroundings and quality of water to Hemlock Lake. It is a trifle over three miles in length and one third of a mile in width, and has a water surface of 648 acres. Its elevation is about 500 feet above the Erie Canal Aqueduct, or about 112 feet above Hemlock Lake. The outlet empties through a narrow gorge into Hemlock outlet about one fourth of a mile from the foot of Hemlock Lake. The fall from the foot of the latter to the junction of the two outlets is only about two feet, so that a small dam constructed below this point would divert the entire outflow of Canadice Lake into Hemlock, thus adding to the water supply of the city about 9 million gallons daily. The total capacity of the two lakes is about 28 million gallons per day. The same sanitary precautions in use at Hemlock Lake are being put into effect at Canadice, and the city has already acquired more than half the shore line. When the work is completed the entire watersheds of both lakes will be practically without

habitations with the exception of one small village and the scattered farms, and these are under constant supervision.

Our abundance of water is used as a factor in our street cleaning. The main streets and the avenues leading to the parks are flushed three and four times a week, removing the flour dust impossible to remove with the brooms during the day. Last year 9 million gallons of water was used for this purpose, flushing 8 500 000 square yards of pavement at a cost to the department of $11.55 per thousand square yards. From the flushing we derive a two-fold benefit, — the cleansing of the streets and the flushing of the sewers.

An important factor in a water-works system, and one which appeals very strongly to the writer, is the method of accounting. Soon after assuming office an investigation of the system in use in the accounting department showed it to be very unsatisfactory in many ways, the chief of which was that it did not in any manner harmonize with the assessors' rolls and showed an entire lack of coördination.

With the object of remedying these defects, as well as to avoid the annual delay in spreading the unpaid water rents on the tax roll, a thorough investigation of the old system was made, and, after a careful study of the conditions, it was decided to install an entirely new set of registers, ruled to show meter rate, flat rate, or frontage tax, as the case might be, on each page.

The accounts have now been arranged by wards and alphabetically by streets, and in the order of house numbers on each street, making each ledger self-indexing without regard to change of ownership. Under each account a full record is kept of all charges against the property for water, either metered or flat rate, together with a record of the service.

An account is opened with each lot in the city, so that, if water pipe is laid in the street, a charge for frontage tax or for the use of water must appear. This frontage tax never before appeared on the records, and the new arrangement greatly simplifies the work of transferring unpaid accounts at the end of the year.

A cordial invitation is extended to any one interested in this particular line to inspect our system in detail.

A pertinent matter came to the writer's attention during our

big fire of 1904. We were obliged to send to Syracuse and Buffalo for assistance, but on the arrival of the outside companies it was found that their hose couplings would not fit our hydrants. Only after a very costly delay were the proper reducers secured and adjusted. The question arose, at that time, of adjacent cities adopting a uniform size for hose couplings and hydrant connections. I think this is a question which might properly come before this convention.

COBB'S HILL RESERVOIR, ROCHESTER, N. Y.

BY JOHN F. SKINNER, PRINCIPAL ASSISTANT CITY ENGINEER, ROCHESTER, N. Y.

[*Read September 22, 1910.*]

This reservoir was proposed in 1891 by Mr. Emil Kuichling, then chief engineer of water works, not only as a distributing reservoir, but for providing additional storage close to the city, against an interruption in the operation of the conduits.

When Conduit II was constructed in 1893 and 1894, a branch was left for later connecting it with Cobb's Hill Reservoir. Ten years later, in 1903 and 1904, 60 acres of land was acquired on the hill at a cost of $123 000. The property was valuable, as at that time it was the best available sand and gravel deposit near the city.

Plans for a reservoir to contain 144 million gallons were prepared and the contract was awarded, July 20, 1905, to Denniston & Co., of Rochester, for $390 805. There were ten bidders, five above and five below the engineer's estimate of $475 000. The work was let at unit prices, ten items appearing in the bidding sheet. As usual in such construction, some additional work developed, so that the final estimate amounted to $504 778.76.

The highest part of the hill was wooded and had to be cleared. A shallow valley occupied a portion of the center of the hill, and the higher ground on each side of this valley was utilized for the embankments.

The reservoir is about 1 500 ft. long by 600 or 700 ft. in width. It is an irregular ellipse and often referred to as the shape of a baby's left foot, the hollow on the north side indicating the position of a gravel pit about 120 ft. deep. This pit was refilled, but the reservoir embankment was kept on original ground in all but two places, — a small pit at the east end and a larger area at the mouth of the natural valley, above referred to, at the west end, just south of the location of the gatehouse. This valley was filled with selected material and rolled in 4-in. layers, making a very compact foundation for the reservoir wall. A tower was constructed at the west end overlooking the work, from which monthly photographs of progress were taken. The excavation was done

FIG. 1.

FIG. 2.

COBB'S HILL RESERVOIR. VIEW OF WALLS AND BOTTOM COMPLETE.

by steam shovel and cars and, in general, the material was ideal for this kind of work.

The reservoir was lined with concrete throughout. The bottom consisted of a 3-in. course of concrete laid continuously in long strips, for convenience about 14 ft. wide; to this the waterproofing was applied, consisting of six moppings of hot coal tar pitch and five layers of single-ply coal tar felt. Above this came the top layer of concrete 6 in. thick, laid in 12-ft. squares with pitch joints.

In anticipation of the cracking of the lower layer of concrete directly beneath the joints in the upper layer (due to change of temperature in the water), which might result in a fault and a rupture of the waterproofing layer, the lower layer of concrete was thickened to 6 in. beneath the joints in the upper layer, and steel reinforcement was placed transversely to the line of the joint in this thickened portion. An interesting laboratory experiment extending over a long period, with the temperatures changed artificially, indicated this method of treatment.

The reservoir wall, constructed in separate blocks of mass concrete, 20 ft. in length, rests upon a foundation course about 18 in. in depth, laid in blocks 10 ft. long. The transverse joint between the foundation blocks was offset 6 in. from the joint between the wall blocks, so that a reduction in the length of a wall block, due to contraction, would not crack the foundation block beneath the joint. The waterproofing of the bottom of the reservoir was carried under the toe of the wall for 2 ft., but at the joints between the wall blocks it was carried 3.5 ft. further to connect with the stop-water or key-way between the wall blocks. This key-way consisted in a channel 8 in. square, set diamond-wise 1 ft. from the face of the wall, half in one block and half in the next. This opening was filled with clay and sand, rammed with a light pile driver specially constructed for the purpose. These 20-ft. wall blocks contained 106 cu. yd. of concrete. A central passage was left through the wall, which saved about one cubic yard per linear foot. This passage is for inspection, the wall being 3.5 ft. in thickness both in front and back of the opening.

A telltale pipe 1 in. in diameter was built into the foundation blocks every 20 ft., opening at one end into the tunnel passage and, at the other end, into the sand and gravel beneath the toe of the

foundation block, the purpose being to indicate by a jet of water into the tunnel if a break occurred in the lining near the foot of the wall. Up to the present time no indication of this kind has been recorded. This tunnel is 7 ft. high and is lighted by electricity. The leakage through the joints in cold weather amounts to about 20 000 gallons per day; in warm weather, it is scarcely appreciable. Recent gagings show less than a gallon per minute for the 3 600 linear feet of wall.

It was originally intended to make a concrete of screened sand and gravel, but early in the work this was changed to run-of-bank, the latter being uniformly good. Volumetric measurements of voids in the material were made daily during the construction of concrete, and it was found that one bag of cement to 6 cu. ft. of sand and gravel produced a concrete a trifle denser than an artificial mixture of 1 part cement, 2½ parts sand, and 5 parts clean gravel.

The wall blocks were generally built in two shifts, no stop being allowed until 2 ft. above the top of the tunnel, though some blocks were made in a single shift. They were built alternately, the intermediate blocks being constructed after the first forms had been removed. The concrete was prepared in a Hains' mixer, dumped into 1-yd. buckets on cars hauled by locomotives, and then handled by a McMyler crane. Ten forms were built for the wall blocks and used repeatedly, as 180 blocks were constructed. The material was brought to the mixer on a belt conveyor, and the concrete for the bottom was hauled on an industrial track by a home-made gasoline motor.

As the reservoir bottom and banks were so securely built, it was thought best to protect the weakest spot, viz., where the 36-in. cast-iron inlet pipe and the two 36-in. cast-iron outlet pipes pass from the gatehouse beneath the high bank at the west end of the reservoir. This was accomplished by constructing a concrete pipe gallery 126 ft. long beneath the bank, leaving openings in the heavy roof of sufficient size to admit a 12-ft. pipe in case of repairs. The 36-in. inlet pipe is laid through the gatehouse and into the reservoir, resting on saddle blocks on the reservoir bottom. It passes through the fountain chamber in the center of the reservoir, which contains a 24-in. riser for the fountain, and just beyond

FIG. 1.
WATER BEING LET IN FOR THE FIRST TIME THROUGH SUBMERGED INLET.

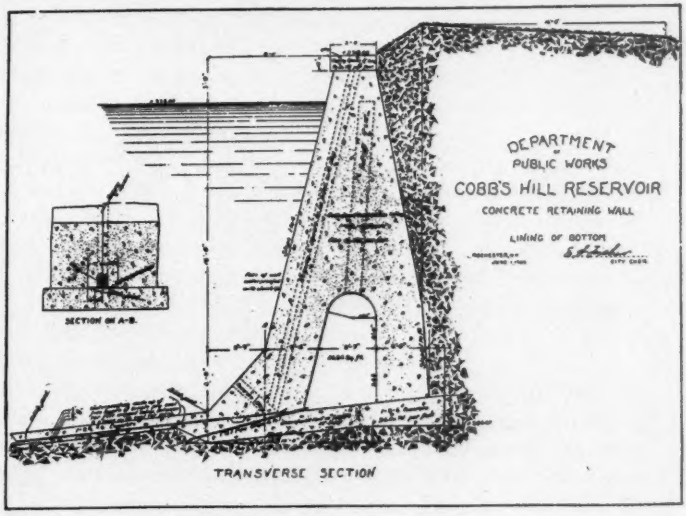


FIG. 2.
CROSS-SECTION OF RESERVOIR WALL.

the riser a 36-in. hydraulically operated gate. The pipe then continues to a submerged discharge located in the center of the circular east end of the reservoir. By closing the "fountain gate," the fountain is put into operation. By opening this gate, the water passes the fountain and enters the reservoir through the submerged discharge.

The reservoir bottom is in general level (with the exception of very slight slopes to facilitate drainage) to a line 50 ft. distant from the toe of the wall. From this line it rises on a 10 per cent. slope to the toe of the wall. This detail did not decrease the total capacity of the reservoir a great deal, but did materially reduce the quantity of masonry in the wall blocks.

The gatehouse substructure is built in the bank at the west end, projecting a little in front of the wall into the reservoir. There are six openings in the front wall, one high and one low 2- by 4-ft. gate into each screen well, a 2- by 4-ft. waste gate at the lowest point, and an arched opening to the overflow chamber, ordinarily submerged. The overflow chamber is provided with a spillway 13 ft. long over which high water may waste directly into a storm water sewer. The gate chambers are immediately back of the screen wells and below the surface level of the water. The gates, made by the Rensselaer Manufacturing Company, are operated hydraulically and can be operated manually by engaging a loose nut in the thread of the rising stem through bevel gears. The tunnel through the reservoir wall is entered from the gatehouse so that inspection can be readily made.

Water was first let into the reservoir October 19, 1908, and the reservoir was completely filled by the following January. On the 8th of April, a 60-mile gale blew from the west, throwing considerable spray over the bank. It was gratifying to note that the solid wave did not, in any case, mount the wall, the reservoir being full and the top of the coping being 3 ft. above high-water level. On the 13th of April, a 30-mile gale blowing from the south also agitated the surface considerably.

The superstructure of the gatehouse was constructed of Barre granite with a green tile roof. A portico was suggested, as the property is to be used as a park and this porch can be used as a shelter. At the foot of the hill, on Monroe Avenue, a by-pass

house was constructed. In it are duplicates of the gates in the gatehouse, as well as by-pass gates for cutting the reservoir out of operation.

A public comfort station is nearing completion on the brow of the hill near the gatehouse. It is built low and will be secluded with shrubbery.

In June, 1909, the water was lowered to make a repair on two of the wall blocks in which it was found that excessive tamping of the clay in the joint had cracked off the face. The cement was rather slow setting, and although the concrete was excellent, it had not yet attained sufficient strength to stand the ramming when the clay was put in.

As the grounds are open to the public, a steel picket fence 6 ft. high was constructed around the reservoir. The fence is built upon a 2-ft. coping, and the sloping bank inside of the fence is paved with concrete down to the reservoir wall coping. Outside of the fence, an 8-ft. concrete sidewalk has been constructed, and a row of pine trees set 16 ft. apart. The slopes have been seeded and driveways constructed, making a beautiful pleasure ground with a sightly outlook over the city. Incandescent lamps have been installed above the line of the fence as a protective measure as well as an addition to the park.

Five specially designed balanced valves for operating the hydraulic gates have been placed in a glass case in the gatehouse, and a gage has been devised for exhibiting at all times the level of water in the reservoir and in the screen wells. This is accomplished by partially exhausting the air above the water surface in the gage glasses.

The area of the water surface in the reservoir, when filled, is 18.6 acres, and the maximum depth of water is 25 ft. Its contents, as stated above, is about 144 million gallons.

Mr. Frederic P. Stearns was consulted in the preparation of the plans and specifications, and Messrs. Dow & Smith were retained in connection with the pitch waterproofing, and Olmsted Brothers in connection with the landscape work.

The reservoir has been in constant operation since its construction and has proved satisfactory both in design and workmanship.

THE PURIFICATION PLANT OF THE ROCHESTER AND LAKE ONTARIO WATER COMPANY, ROCHESTER, N. Y.

BY JAMES M. CAIRD, CHEMIST AND BACTERIOLOGIST, TROY, N. Y.

[*Read September 21, 1910.*]

The power and purification plant of the Rochester and Lake Ontario Water Company is located on the shore of Lake Ontario, about one and one-fourth miles west of the village of Charlotte, N. Y.

Lake Ontario, the inexhaustible source of supply, is 180 miles long, 60 miles wide, with an area of 6 300 square miles. The greatest depth is supposed to be about six hundred feet, while the rise and fall is about fifty-four inches. The drainage area, within New York State, is 12 400 square miles, or about one fourth the area of the entire state.

The intake, which is about one and one-fourth miles west from the lighthouse pier at the mouth of the Genesee River, is of 24-inch cast-iron pipe extending four thousand feet from the shore in water forty feet deep.

The plant was placed in operation on the fifteenth day of December, 1904, and daily records have been kept since January, 1905. In January, 1905, the total pumpage was about one million gallons per day, while at the present time the average pumpage is over four million gallons per day.

The water is sold in a part of the city of Rochester and to several suburbs thereof. All water is sold by meter, there being at the present time 2 000 meters in use. The distribution system is composed of about forty miles of mains, the sizes of which range from four to twenty inches.

The power for operating the plant is obtained from three water tube boilers of three hundred horse-power each. Previous to the autumn of 1907 the lake water flowed direct to the suction of the high-duty pumping engines which forced the water through the filters and into the distribution system. There are two high duty

cross-compound Corliss fly-wheel type pumps, each of three million gallons daily capacity.

The filter plant consists of eight pressure filters, each 8 feet diameter and 25 feet long, having a sand area of 200 square feet each, or a total of about one twenty-seventh of an acre. There is a pressure of 235 pounds on the filters. They are washed when they show a frictional resistance of 15 pounds. About two and one-half per cent. of the water filtered is used in washing the filters. When the filters are cleaned the frictional resistance is about four and one-half pounds when operating at the rate of 81 million gallons per acre per day. A resistance of 7 pounds is shown when operating at the rate of 148 million gallons per acre per day. The sand in the filters is about 3 feet in depth, has an effective size of .46 mm., uniformity coefficient of 1.51, while 60 per cent. is finer than .74 mm.

A standpipe which is 15 miles from the pumping station is used as a storage reservoir. This standpipe is 150 feet in diameter and 20 feet deep, having a capacity of 2 640 000 gallons.

Lake Ontario is subject to severe storms, and at such times the water becomes quite turbid and contains large numbers of bacteria. When the lake became turbid from a storm it was impossible to remove the turbidity by the filters, although the bacterial efficiency was satisfactory, as the coagulant did not have sufficient time to entangle the finer particles which made up the turbidity. To overcome this condition a coagulation basin was installed and placed in operation in the autumn of 1907, since which time no trouble has arisen from turbidity of the filtered water. This coagulation basin, which is of wooden construction, is 6 by 48 by 201 feet and contains about 430 000 gallons. The installation of the coagulation basin has resulted in the saving of water used for washing filters, while the total bacterial efficiency of the plant is somewhat higher. The water is lifted by a low lift pump to the coagulation basin and flows by gravity to the suction of the high duty pumps. It is not necessary to operate the coagulation basin when the turbidity of the lake water is below 10 parts per million.

Several tests of the plant were made before the basin was installed, the average bacterial efficiency being 87.38. per cent. During these tests all samples of the unfiltered water contained the coagu-

lant, as no provision had been made whereby samples of the untreated lake water could be obtained. Since the installation of the coagulation basin provision has been made so that it is now possible to obtain samples of the raw water before the coagulant has been added.

Sulphate of alumina is used as a coagulant; at times calcium hypochlorite is also used. The use of the calcium hypochlorite has greatly reduced the cost of operation, while at the same time the high bacterial efficiency is maintained. The average amount of sulphate of alumina used is about 0.7 grams per gallon, equal to about 100 pounds per million gallons of water. The average amount of calcium hypochlorite used is .048 grams per gallon, or about 6 pounds per million gallons of water. In 1907 a building was erected for the chemical tanks, storage room, and laboratory. The coagulants are dissolved in wooden tanks, 5 feet in diameter and 15 feet high, and are applied to the raw water through gravity orifice feed boxes.

Some trouble, due to the odor and taste produced by algæ in the raw water, has been encountered in the operation of the plant. At the time of the algæ troubles the following organisms were found in the raw water in large numbers.

September, 1907.	January, 1909.	February, 1910.
Dinobryon.	Cymbella.	Cocconema.
Navicula.	Fragilaria.	Cyclotella.
Synedra.	Synedra.	Synedra.
Cosmarium.	Eudorina.	Microcystis.
Crenothrix.	Crenothrix.	Crenothrix.
Volvox.	Cladothrix.	Volvox.
Nitzschia.	Stephanodiscus.	
Asterionella.	Asterionella.	
Anabæna.	Himantidium.	
Tabellaria.	Cocconeis.	
Cœlastrum.		

It is to be noted that the algæ gave trouble during the winter months on two occasions. To relieve the trouble due to the algæ, copper sulphate has been used with good success.

At the time of the algæ trouble of February, 1910, an attempt was made to treat the growth with calcium hypochlorite, but the

results were not satisfactory. Sufficient hypochlorite was used so that the treated water gave the reaction for free chlorine.

Commencing with April, 1909, daily chemical and bacterial examinations of the water from various parts of the system have been made, the work being in charge of Mr. John F. Amos, chief engineer.

The composition of Lake Ontario water during the year (April 1909 — 1910) was as follows.

RESULTS IN PARTS PER MILLION.

	Maximum.	Minimum.	Average.
Turbidity	80	0	9.5
Color	25	0	5.0
Alkalinity	99	92	96.3
Hardness	110	96	103.5
	PER C.C.		
Bacteria	59 600	50	5 807

The bacterial efficiency of the plant during the year was as follows:

Bacteria removed by basin	89.28	per cent.
Bacteria removed by filters	49.60	" "
Bacteria removed, *total*	96.60	" "

Calcium hypochlorite was used during part of the year.

The average bacterial efficiency of the plant during April, May, June, and July, this year, was 99.23 per cent.

The filtered water is always free from color and turbidity, the efficiency in this respect being 100 per cent. During the year, 1 017 samples of 1 c.c. each of the raw water were examined for B. Coli-communis; 293, or 28.8 per cent., gave positive results. Of the 758 samples of 1 c.c. each of the settled water examined, 31, or 4.0 per cent., gave positive tests for B. Coli-communis. Of the 1 020 samples of 1 c.c. each of the filtered water examined for B. Coli-communis, 34, or 3.3 per cent., gave positive results.

The purity and value of the water may be inferred from the fact that the typhoid fever death rate among the consumers of the filtered water is very low, and that the Eastman Kodak Com-

pany use the water in their delicate photographic work, as do also the New York Central Railroad, the Buffalo, Rochester & Pittsburg Railroad, and many other large consumers, for boiler purposes.

DISCUSSION.

JOHN F. SKINNER, ESQ.* I visited the pumping station and filter plant of the Rochester and Lake Ontario Water Company, a number of years ago, and found it an extremely interesting plant. There is one matter, however, that I would like to call to Mr. Caird's attention, and ask if it has come to his notice. In Fairport, a village about ten miles from here, one large factory, and I think several others, are supplied with this water; some typhoid has developed in the past in this village, and the doctors, I understand, lay the typhoid to this filtered water, as the patients generally, it is stated, have been employed in places where this water is used. There is a case at the present time, in one of the hospitals in this city, coming from Fairport, and it is alleged to have been due to this water. I would like to ask Mr. Caird what he has to say about it.

MR. CAIRD. I might say that about two years ago I came here and investigated some cases of typhoid fever which originated at Fairport, as I understood. Of course we supply other villages beside Fairport, but we found no typhoid fever in the other places. They get the same water, and I felt that if the typhoid was due to the water it would have shown up all along the line. As you know, there is a long line of pipe, and there are several fair-sized communities which receive this water. Typhoid fever is a very hard thing to trace to its origin, particularly when we have only one case. Then again, it is just the close of the vacation time now, when we generally expect typhoid fever will develop. I have not heard anything about this last case which the gentleman speaks of, and of course know nothing about its history. One needs to have a pretty full history of a case before deciding its source, for if there is but one case there is very little to work on.

* Assistant City Engineer, Rochester, N. Y.

DR. ROBY.* If any of you have attempted to trace an epidemic of typhoid, or even a few cases, you know how difficult it is to do it. The patients themselves are very ignorant about the cause of their disease, and they most always think it is due to the plumbing or to anything rather than the real cause. I was in Lockport, the other day, visiting a boy who had typhoid, and I think I asked him the question seven times before I could finally get out of him that he had been on a farm before the two weeks' time after which he should have come down with the fever. For six times he denied absolutely that he had been out of Lockport, but the seventh time he acknowledged he had been on this farm.

As Mr. Caird just said, if this water carried the typhoid, we ought to find it all along the line. There has not been a case, — and I have looked up, I think, every single reported case which has occurred in Rochester in the last fourteen months, traceable to Ontario water. I will not say anything about Fairport except that if cases have occurred in Fairport, they ought to have occurred in Brighton (part of Rochester) and in the other communities which use the water, if the Fairport cases were due to it. It is impossible to imagine that they would all be located in one town. I am very positive there hasn't been any case in Rochester which could be traced to Ontario water.

We have a very interesting epidemic of typhoid at this moment. There is a bay down here on the lake shore, and dotted all around this bay are a lot of summer resorts. We have had, I suppose, fifty cases of typhoid fever reported since the 1st of July. Every single case which has been reported, with the exception of about four or five, have been to some other place. For example, one case was infected in Pulaski, another case in Erie, and other cases in Buffalo, and so on, until you have a residual of about thirty cases, and almost every one of those thirty cases within two weeks previous to the time when they came down — that is, the time within which the disease would show itself — had been to this little bay. They had not all been to any one spot on the bay, but some had been to Sea Breeze, and others to other places. My only explanation of the thing is that the bay water itself is infected, but not badly infected, and that in some way or other these

* Of the Health Bureau, Rochester, N. Y.

people got the infection out of the bay. The orphan asylum people went up to the bay with ninety children, on the 3d of August, and on the 17th of August the first and only case came down. I could not find that the child had done a single thing different from the rest of the ninety, yet I am quite positive that the child was infected at Sea Breaze, because we have had seven other cases infected at Sea Breeze. So far as the filtered water is concerned, I am perfectly satisfied that there never has been a case of typhoid traced to it.

MR. CAIRD. I might state, in connection with the examination of the water, that at times we are using hypochlorite, and we see bacterial plates which remain sterile. I do not believe in a hundred per cent. removal of bacteria, and if the plates are sterile we record at least one per cubic centimeter. Of course a cubic centimeter is a pretty small quantity to examine, and we don't want to say that the filters remove one hundred per cent., and so we put down at least one for every sterile plate. The bacteria in the filtered water during the last three or four months averaged two or three per cubic centimeter.

MR. W. C. HAWLEY.* There is one thing in Mr. Caird's paper which struck me particularly. I understood him to say that the floating of that partition baffle wall had no injurious effect upon the operation of the sedimentation basin. Is that correct?

MR. CAIRD. That is correct. Our bacterial average remained practically the same.

MR. HAWLEY. That is very interesting and very instructive. About eighteen months ago we started to construct a mechanical filter plant. One of the important adjuncts to that plant were sedimentation basins. We asked for proposals from various manufacturers of filter plants, simply giving them our conditions and asking for certain results from the plant, which they might design themselves. Each of the plans which were submitted had elaborate schemes of baffles in the sedimentation basins. We objected to those on the ground that there were more or less dead spaces where the water would stand, and there would be places where the velocity would be considerable. We finally, under the advice of our consulting engineer, did away with all the baffles

* Engineer and Superintendent Pennsylvania Water Company, Wilkinsburg, Pa.

except one midway in the sedimentation basin at right angles to the direction of flow, and so far our results are all that we would expect. The two sedimentation basins are each about 60 ft. wide, 150 ft. long, and about 20 ft. deep. I believe that this matter of baffling has been overdone, and this is confirmed by Mr. Caird's experience.

THE PRESIDENT. I should like to ask Dr. Roby if at these resorts on the bay, which he spoke of, they drink the bay water.

DR. ROBY. No, they do not. That is the only explanation I can give why the cases have not been widespread. If there was a well which was infected, which was in common use, it seems to me that we would have very much more typhoid. I may be wrong about it, of course, but the only way I can figure it is that either a few people have gone in bathing in the bay itself and have swallowed water accidentally, or a milk can has been washed in the bay water and one or two typhoid organisms have been left in the can, and they have grown in the milk, and some particular person has happened to get the milk, or something of that sort. People very seldom use the bay water; they use spring water. The only thing which was in common, at these different points on the bay, in all the cases, was the bay water; and that is why I thought it must be the bay water. All the cesspools drain right into the bay, and besides that, the bay has a drainage area up through the country. Last year we had no cases from the bay, but it seems that some typhoid carrier has gotten the typhoid organisms into the bay water this year, when they didn't last year.

MR. EMIL KUICHLING.* I should like to inquire of the doctor if flies might not have played a very important rôle in these cases of which he speaks. Every one who has ever seen a children's picnic knows that there is ample oportunity for that kind of infection, as the places where the little ones seek relief in the brush are usually not far from those where food is served; therefore the probability that the food was infected by flies is a good deal stronger than that this large body of water became infected from any point on the watershed.

Much is said about water carrying typhoid fever germs to great distances, and it is very convenient to attribute an outbreak of

* Consulting Engineer, New York, N. Y.

fever to infected water. We should consider, however, that as water-works engineers, we have the same right that medical men exercise when they step over into the domain of some other profession and say, "Oh, you are all wrong; you must accept our standards; we are a great deal better able to judge of this than you are." Turn about is fair play, and I only suggest that there are limitations in medical and sanitary science, just as there are limitations in chemical and mechanical science.

It is therefore necessary to eliminate scrupulously all other possible sources of infection before fixing the blame upon one particular source. If there is anything in the fly theory, surely flies are very liable to have caused the trouble at the picnics mentioned.

MR. CAIRD. I might add that I had an interesting experience last summer. Twenty-three cases of typhoid fever came up in a certain place within a week or ten days. Of course, as usual, the water supply was blamed. The doctors had it all fixed, only they didn't have any history of the cases. The first thing I did was to get the history. I found that every one of these persons had been camping up the river and that they were all in the habit of going into the river to bathe. Ten miles up the river there is a city of 18 000 inhabitants, and I found 12 cases of typhoid fever up there. Of course the sewage from that city went into the river. Upon investigation I did not find one of those cases where the family admitted, or the patient admitted, that the physician had given any instructions as to what to do with the stools, and so they were just dumped into the toilet and washed right down, without any germicide being used at all, and came down the river where these men went in swimming. That illustrates the importance of the treatment of the discharges from typhoid patients, for if they are put into the sewer they are liable to cause trouble unless they have been treated, and treated properly.

MR. R. W. POST. There is an outhouse within fifty feet or so of one of the main picnic tables at Sea Breeze.

DR. ROBY. In answer to Mr. Kuichling, I will say that I am not by any means sure of my conclusions, and I did not mean to say that I was sure. But I think the chances are that the source of contagion was the bay water, because it seems to me difficult to imagine that all these places, which are some distance apart,

could be infected, for instance, by flies from a common source. I doubt whether flies would get as far as from Sea Breeze across the bay and to these other places. Of course they might, — I suppose it is within the range of possibility, — but I doubt it; and the only thing in common is the bay water. I have looked up the milk supply, and it is different in the different places. The water that they drink is different at all these different places, and the only thing in common is the bay water itself. That is the reason I arrived at my conclusion, but perhaps it is a wrong one.

MR. CAIRD. May I ask the doctor if he finds that people when they do have a case of typhoid pay much attention to the discharges of the patient.

DR. ROBY. I think they do, but I don't believe you can ever control it in that way, for this reason: the patient may not go to a physician for a long time, and it may take the physician quite a long time to make his diagnosis.

MR. LEONARD METCALF. I should like to ask Mr. Hawley to say one word with reference to the method of introducing the water into their sedimentation basin and taking it off, for it seems to me that is important as well as the method of baffling.

MR. HAWLEY. The water is introduced at one end of each sedimentation basin through a number of 8-in. vertical pipes, which discharge about a foot above the surface of the water on to a floating plank platform. There is a strip of 2- by 4-in. timber on the side of the platform towards the basin. The water flows back toward the end of the basin, thus disturbing the water in the basin as little as possible. It then flows to the other end of the sedimentation basin, passing under the reinforced concrete baffle wall. The water has to dip down under and come up the other side, and then is taken out at the other end of the basin into a trough through a number of rectangular holes about eight inches square, placed all along the trough for the whole width of the basin and about a foot below the surface of the water.

DR. J. ROBY (*by letter*). Since the above report was made, it has been discovered that the domestic water supply of Rochester furnished by Hemlock Lake has been contaminated over a certain section of the city. There are two systems in use here: the Hemlock domestic service, depending on gravity for its force and usually

having a head of about 58 lb.; and the Holley system, taking water from the river for fire purposes. In some way or other the gate connecting these two services was left open and consequently the river water was pumped into the Holley mains. When this was discovered, it was found that apparently only that part of the city lying north of Allen Street and west of the river (about one fourth of the area of the city) showed contamination of the water. None of this water showed contamination by colon bacilli when tested, but as it has been going on all summer — and as some twenty cases of typhoid have developed right in this region and explainable by no other cause — it seems safe to say that at times this water contained typhoid bacilli.

Some of the cases previously ascribed by me to contamination at the bay were undoubtedly infected by this water, but I am inclined to think that there is, or was, contamination of the bay water also. As this section of the city has a population of some 40 000 to 50 000 people, it seems also evident that a large body of water may be contaminated in some spots and not in others. In fact, it seems to me highly probable that a mass of fecal material containing typhoid bacilli might remain undissolved for some time and only infect a few cubic feet of water in its immediate vicinity. Much further study will be necessary in this case; but it seems to me now that these are safe conclusions. The typhoid in Rochester this summer has come from four sources:

1. Those evidently infected out of town.

2. Those who did not live in the suspected area but had been to the bay, and were probably infected by bay water.

3. Those who had not been out of the city at all but who certainly drank the suspected water.

4. Those infected by contact with other cases, as nurses at hospitals.

STEEL PIPES FOR WATER WORKS.

BY E. KUICHLING, C.E.

[*Read September 22, 1910.*]

The subject of steel pipes for water works is attended with so many theoretical complexities that it becomes necessary to be governed largely by the results of the closest observation of such structures in as many different localities as possible.

The chief reason for this empiricism lies in our lack of exact knowledge relating, firstly, to the chemical composition of the metal and its durability when placed in various kinds of soils, and, secondly, to the magnitude of the external forces which act on the pipe after being laid and placed in service. Although much has been printed in regard to these features, there is still room for extended scientific investigation in consequence of important contradictory evidence on vital points, and it is the purpose of the writer to bring some of these to your notice.

Steel pipes are of quite modern origin, as the use of soft steel for making boilers and tubes began in this country only about 30 years ago. Previous to that time wrought iron was generally employed for these purposes, but unfortunately its use for making large pipes for the conveyance of water and sewage was very limited, owing doubtless to its greater liability to corrosion than cast iron. Prior to 1870 it had been adopted for permanent works in a number of places where the liquid was carried under high pressure, and also where rigid foundations could not be secured readily, as in deep valleys, river and canal crossings, bogs, etc.; and in these cases efforts were made to provide the wrought iron with protective coatings of various character. Of its use for temporary construction, no mention need here be made.

With the growth of municipalities and the corresponding development of public water supplies, it gradually became necessary to make pipes of considerably larger size than formerly. To meet this demand, cast-iron pipes having a diameter of 6 feet were produced in a few foundries, but it was soon found that their strength was inadequate for ordinary service, and if made sufficiently thick

their cost would be much more than that of a suitable riveted wrought-iron pipe. Equality of cost for equal strength was also found to occur at diameters of from 2 to 4 feet, depending on the respective market prices of the two metals, even if the acknowledged greater durability of cast iron was taken into consideration liberally.

Although the advantages of large wrought-iron pipes over those of cast iron, from the standpoints of economy and original strength, were early recognized, yet the lack of knowledge of trustworthy means of preventing corrosion was the principal obstacle to their general use. A great number of preservative coatings and processes were devised, but none of them seems to have been entirely satisfactory, and for this reason cast-iron pipes were generally preferred by hydraulic engineers in cases where the required diameter was moderate and the utmost economy was not imperative. Under other conditions an astonishing number of large conduits have been built during the past 40 years of wrought iron and soft steel plates, and it becomes of great interest to learn something of their present condition.

A long list of such conduits is here omitted to save time and space, and of their condition comparatively little has come to the writer's knowledge, except that none appears to have been completely destroyed by corrosion. More or less damage from this cause, however, has been reported in a few cases, and particularly where the metal was steel. The old wrought-iron pipes seem to have given relatively little trouble, and for this reason, as well as from many similar observations in various other metallic structures, the opinion that wrought-iron possesses inherently a much greater resistance to rusting than soft steel is rapidly growing, notwithstanding that numerous experiments to the contrary have been cited in many papers and treatises written by eminent modern metallurgists.

In support of this opinion, the writer ventures to cite a few experiences. For reasons of economy in the construction of the original water works of the city of Rochester, N. Y., it became necessary during the years 1873–5 to make use of a large quantity of 36-inch and 24-inch riveted wrought-iron pipe, ranging in thickness from $\frac{1}{4}$ inch to a little more than $\frac{1}{8}$ inch. Much care was

taken to provide it with a thick bituminous coating; but in the course of transportation this coating suffered considerable damage, which was sought to be repaired in the field. In 9.62 miles of 36-inch pipe, $\frac{3}{16}$ inch thick, no perforation of the sheets by rusting occurred until 1894, when 26 small holes were plugged, several holes being found occasionally in a single plate. In 1896, 18 more holes were plugged under like circumstances; in 1899 and 1900, 10 additional holes appeared, and since the latter year no more have been reported; total in 36 years, 56 small holes, none more than $\frac{1}{4}$ inch in diameter, and all easily stopped without interrupting the flow through the pipe; probable number of damaged plates or sheets, 25 or 30; total number of plates used in the line, about 11 300; pipe laid mostly in clayey soil. The coating was a mixture in nearly equal proportions of refined Trinidad asphalt and coal-tar pitch.

In 2.93 miles of 24-inch pipe of the same conduit, with thicknesses of $\frac{3}{16}$ and $\frac{1}{4}$ inch, only a very few perforations by rust have been reported as occurring in 1894. The most interesting case, however, is that of the 24-inch riveted wrought-iron feed pipe of the Holly direct pressure system in the same city, which was laid in 1874 for the purpose of carrying an alternate supply of impure river water to the pumping station. Its length is about 3 300 feet, and its thickness is a little more than $\frac{1}{8}$ inch. Like the aforesaid conduit, it was protected by a bituminous coating. The water pressure is insignificant and the supply is utilized during only a few days in each year, when the race, or water-power canal, from which the normal supply to the plant is taken, is emptied for general repairs. During the rest of the time the pipe is empty and drained by a 6-inch blow-off connection into a large sewer. The gases in this sewer are thus afforded access to the interior of the pipe in the vicinity of the blow-off. The street soil in which the pipe is buried for a length of nearly 2 000 feet, is rich in organic matter. Under these unfavorable conditions a long life for this section of the pipe was not expected.

For 25 years no repairs were needed, and little was known of its actual state of preservation. In 1899, however, it was deemed expedient to examine it closely, and the greater part of said length of 2 000 feet was fully exposed. The pipe was then inspected

closely by a number of thoroughly experienced metal workers, and was found to be so little corroded that its contemplated replacement with cast-iron pipe was regarded as unnecessary. It was accordingly left in place after applying a fresh coating of hot asphalt and coal-tar pitch to the exposed external surface, and has remained in good service up to the present time, with a life of 36 years.

In 1873 the writer investigated the condition of a number of $\frac{3}{4}$-inch and 1-inch wrought-iron gas service pipes in Rochester, which had remained undisturbed in the ground for more than 18 years. None of these pipes had received any preservative coating, and in most cases the exterior surface was then found to be somewhat corroded, but on removing the earthy crusts no deep pittings were observed. Several of them are still in place after a life of at least 55 years, the remainder having been removed when the dwellings were replaced by commercial buildings that needed larger supply pipes. It also is very probable that a search of the records kept by the gas companies of our cities would reveal a multitude of similar instances.

Mention of numerous other observations of like character by the writer is here omitted for lack of space, and in contrast thereto a few of his experiences with soft steel pipes will be cited. The second conduit of the Rochester water works was constructed in 1893–4 in consequence of the insufficiency of the former supply. Its principal feature is a riveted steel pipe 38 inches in diameter, nearly 26 miles long, and ranging in thickness from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch. Three different kinds of protective coating were applied to the metal in different sections of the work. The first one was a Californian asphalt or maltha, which appeared to be satisfactory and had been used very successfully in other localities, but soon showed signs of disintegration here; the second was a mixture of refined Trinidad asphalt and coal-tar pitch, like that which had been used on the old wrought-iron conduit; and the third was the baked or "japan" coating which had meanwhile been devised by Prof. A. H. Sabin.

The writer ventures to assert that the utmost care was taken by all of the city's employees to secure the best quality of metal and coating, as well as good workmanship in the field; furthermore,

there was no indication, on the part of any of the contractors, of an intention to slight any part of the work or to use improper material or mixtures. The steel may therefore be regarded as representing the best metallurgical skill and experience available at that time, which was fully thirteen years after the art of steel making had been developed in this country to such an extent as to supplant the production of puddled wrought-iron on a large scale. The history of this conduit, however, shows that in spite of all the care that had been expended on its construction, serious corrosion of the metal began to appear in 1901, or only seven years after its completion. Perforation by rusting was then discovered in a number of plates at seven different localities in the two sections of pipe which had been coated with Californian and Trinidad asphalt. Examinations were also made in the same year at 25 other localities in the entire route where leakage had not yet appeared, and in some of the excavations more or less pitting of the steel was seen. The soil was mostly a stiff red and blue clay.

A careful study of the problem was made by Prof. F. L. Kortright, of Morgantown, W. Va., during 1901 and 1902. No corrosive acids or gases were found in considerable quantity in the soils and ground water, and the cause of the rusting was ascribed mainly to the action of mill scale, oxygen, and free carbonic acid, at points where the coating was defective. To remedy the trouble, he advised a thorough scraping of the metal and the application of two coats of mixed red lead and graphite paint, followed by two additional coats of mineral rubber paint or Truscon Special paint. The practice is to expose the pipe fully wherever extensive corrosion is discovered, scrape off the defective coating, and apply the said four coats of paints mentioned to the entire surface; the excavation and recoating process are then continued in both directions until all sign of rusting disappears.

Up to the end of 1907, a total of 205 perforations of the steel by corrosion were found and repaired. All of these but one were in plates $\frac{1}{4}$-inch thick, and it is interesting to note that only about 16 occurred in the plates made by the Pennsylvania Steel Company and protected by the Sabin coating, while the remainder occurred in the plates made by the Carnegie Steel Company and protected with Californian and Trinidad asphaltic coating. These figures,

however, do not indicate correctly the respective merits of the two metals, as the length of pipe made of Carnegie Steel Company plates $\frac{1}{4}$ inch thick is somewhat greater than that made of Pennsylvania Steel Company plates of the same thickness; but it is certain that the latter plates exhibit a much greater resistance to rusting than the former.

Both metals were prepared by the open-hearth process from the same specification, which required the impurities to be limited to the following percentages: Sulphur and phosphorus, each 0.06; manganese, 0.60. The physical tests called for a tensile strength ranging from 55 000 to 65 000 pounds per square inch, with an elastic limit of 30 000 pounds, and an elongation of 22.5 per cent. in a length of 8 inches; also for various tests as to cold-bending, punching, drifting, and forging. The inspectors reported full compliance with all of these requirements, but it may be of interest to remark that the analyses of the Pennsylvania Steel Company's metal usually exhibited a considerably smaller percentage of manganese than was contained in the product of the Carnegie Steel Company. In the light of recent investigations on corrosion, this fact may account for the much larger number of perforations that have appeared in the latter metal.

The experience with the riveted steel conduit that supplies drinking water to the city of Portland, Ore., is very similar. This conduit is about 24 miles long, and varies in diameter from 42 to 33 inches, with plate thicknesses ranging from $\frac{3}{8}$ inch to $\frac{1}{4}$ inch. There are also several lines of smaller riveted steel distributing pipe, from 30 to 18 inches in diameter and from $\frac{1}{4}$ inch to $\frac{1}{6}$ inch thick. All of these pipes were made of eastern steel plates in 1895–6, under the same general specifications that were used for the Rochester conduit, and were well coated with Californian asphalt or maltha. After nearly nine years, leakage due to rust perforations appeared in a number of 35-inch conduit plates $\frac{1}{4}$ inch thick, laid in clayey soil. On exposing the pipe for repairs, an extensive pitting of the metal was found, which led to an examination thereof in 1905 at many other points in the route, and the discovery of more damage of like character. Since that time perforations have occurred in plates $\frac{1}{4}$ inch thick.

In his report on the subject, dated November 27, 1905, the

engineer of the Portland Water Board, Mr. D. D. Clarke, states that the severest corrosion occurred where the pipe was laid in clay, and that little injury from rust was observed in sandy and gravelly ground. This implies that the moisture in the clay may be the principal cause of the active corrosion, but as no chemical examination of the clay was made at the time, it may yet be found that the composition of the metal is more at fault. Mr. Clarke also remarks that in all cases where thin modern riveted conduits have exhibited a long life, the metal was wrought-iron.

Another interesting instance of the early corrosion of steel plates is also afforded by the 48-inch riveted steel force main of the New Bedford, Mass., water-works. The plates were all $\frac{5}{16}$ inch thick, the length of the line is 8.25 miles, the coating was Californian asphalt, and the work was done in 1896. Trouble with electrolysis in the distribution system led to several close examinations of this steel pipe during the past nine years, although no perforations have yet appeared. The investigations made in 1901 showed some external damage by electrolysis at a certain locality. In 1908 and 1909, the interior of the pipe was inspected, and it was found that the asphaltic coating had become very brittle, also that there had been a large increase in the number of tubercles since 1901. The heaviest tuberculation was near the field-made joints, and was more intense on the bottom than upon the sides and top. Beneath the tubercles were pittings, many of which were from 0.075 to 0.095 inch in depth. An abundance of large blisters in the coating was likewise found. These blisters were filled with water, but the metal underneath was free from rust and pits.

In contrast with the preceding cases of rapid corrosion of steel plates, a number of instances might be cited where similar plates have apparently been much more resistant. The most notable one is the 48-inch riveted steel conduit of the city of Newark, N. J., which was constructed in 1890–1, and in which many plates only $\frac{1}{4}$ inch thick were used, the protective coating being Californian asphalt or maltha. This conduit is now 19 years old, and the writer has not learned that any perforations by rusting have yet occurred therein.* In the other cases of which the writer received

*Since the reading of this paper, it has been reported in *Engineering Record* of October 8, 1910, p. 412, that a leak by corrosion occurred in the Newark 48-inch steel conduit in August.

favorable reports, the examinations were not very extensive and the plates were more than $\frac{3}{8}$ inch thick.

It is very evident from the foregoing that the thickness of the metal is a highly important factor in estimating the durability of a water pipe, whether the same be made of wrought-iron or soft steel. The statement is frequently encountered that the rate of corrosion reduces rapidly after a very thin film of metal on the surface has been destroyed by rusting, and that a great many years would be necessary to effect a loss of $\frac{1}{16}$ inch in the thickness of a plate. This may be true if the corrosion is of uniform intensity over the entire surface, but unfortunately, it generally happens that the action is localized so as to produce pits of more or less depth between which the metal retains its original thickness. A thin plate will accordingly give evidence of perforation much sooner than a thicker one, and thus lead to an earlier examination of the condition of the structure.

The development of pits is regarded as proof that the metal is not homogeneous in composition; hence it follows that in dealing with mixtures or alloys, the different ingredients should be diffused as uniformly as possible throughout the entire mass. In the old method of fabricating wrought iron, such diffusion of unavoidable impurities was accomplished by the laborious process of puddling, but in the modern method of making steel, the tendency has been to minimize the work of thoroughly mixing together the various constituents, particularly the manganese, upon which much now appears to depend.

The manganese is added for certain specific purposes, not quantitatively as a rule, but according to the views of the iron-master in charge of the furnace, by throwing lumps of ferro-manganese into the molten metal, either in the furnace or in the ladle into which it has been poured. An intimate mixture or diffusion of the material does not usually take place in this practice, and even when an effort is made to obtain it by pouring the contents of the ladle into another empty one, it still happens that when the molten metal cools, a segregation of the impurities will occur;

1909. The pipe had here been laid in swampy soil, and while repairing said leak an inspection was made of an adjoining steel pipe laid in 1896. This newer conduit was also found to be corroding, but not to the same extent as the older one.

that is to say, the impurities do not remain distributed uniformly or homogeneously through the solidified mass. It must therefore be remembered that the wrought iron and steel usually encountered in engineering work is not a homogeneous pure metal.

The corrosion or decay of iron and steel thus becomes one of the leading questions of the day among engineers. Under the action of natural agencies alone, this decay is often much more rapid than that of wood, while in many other cases it is extremely slow; and on investigating the subject historically, it will be found to be attended with numerous contradictory observations which make its discussion very difficult.

Definition of Terms. It is important to have, in the outset, a clear definition of what is meant by the words *iron* and *steel*. By *iron* the chemist means a pure element of matter, while the metallurgist means thereby a more or less varied mixture of this element with other elements. Absolutely pure iron does not seem to exist in nature, or to be capable of production by the usual processes of manufacture on a commercial scale. As commonly known to mankind, iron is always an impure metal owing to its peculiar property of readily combining with or holding in solid solution nearly all of the other elements. It has also been found that very small quantities of impurity suffice to produce great changes in its physical characteristics, and for this reason experts often scrutinize very closely the hundredth of one per cent. of some of its principal impurities, which are carbon, silicon, sulphur, phosphorus, oxide of iron, and manganese.

By *steel* is meant an alloy or intimate mixture of pure iron with several other elements, the principal of which is carbon, and by varying the proportions a great variety of steels is produced which have widely different physical properties. It is, however, impossible to consider in this paper all kinds of commercial iron and steel, and hence the discussion will be limited to the few varieties alone which are of particular interest to water-works' engineers. These varieties are the cast iron, wrought iron, and mild or soft steel commonly used for making pipes.

Cast Iron. As usually understood, cast iron is not an alloy but an aggregation of chemical and mechanical compounds. It contains more or less of the impurities found in both the ore and

the fuel used in its production. Its principal characteristic, however, is the large percentage of carbon which it holds in chemical and mechanical combination. When used for making water pipes and machinery, its composition is generally within the following percentage limits: Graphitic carbon, 2.50 to 2.90; combined carbon, 0.35 to 0.45; silicon, 1.50 to 2.00; sulphur, 0.07 to 0.10; phosphorus, 0.50 to 0.60; manganese, 0.31 to 0.40. Tensile strength from 12 000 to 21 000 pounds per square inch.

By reducing the graphitic carbon to 1.50–2.00, the silicon to 0.70–1.20, the sulphur to 0.05–0.06, the phosphorus to 0.40–0.50, and increasing the combined carbon to 1.15–1.30 per cent., a much tougher and stronger material will be obtained, as the tensile strength will then rise to 30 000–35 000 pounds per square inch.

Wrought Iron. In the fabrication of wrought iron, most of the impurities of cast iron are eliminated by the agencies of heat and oxidation, so that the final product contains from 98.5 to 99.5 per cent. of pure iron. It is characterized by a much higher melting point than either cast iron or steel (1500 to 1600° Cent. as against 1100 to 1200° Cent. for cast iron, and 1350 to 1450° Cent. for steel) and by its malleability. Its chemical composition is generally within the following percentage limits: Combined carbon, 0.02 to 0.25; silicon, 0.02 to 0.10; sulphur, 0.001 to 0.10; phosphorus, 0.001 to 0.10; manganese, 0.001 to 0.25; slag and oxide, 0.30 to 1.25; pure iron, 98.5 to 99.5. Tensile strength from 40 000 to 50 000 pounds per square inch.

The undesirable impurities are mainly carbon, silicon, sulphur, and phosphorus. Most of these can be removed by prolonging the heating and puddling processes by which the metal is made from molten pig iron; but as these processes are slower and more expensive than those involved in the fabrication of modern soft steel, wrought iron has gradually been supplanted by the cheaper material for most industrial purposes.

Mild Steel. Many varieties of mild steel are made by both Bessemer and open-hearth processes, which differ little in chemical composition from wrought iron, except that they contain no intermixed slag. It is said that carbon is the most important constituent of steel, as it tends to harden the metal and also to increase its tensile strength. These properties, however, are more or less

incompatible with ductility; hence in ordering steel for purposes wherein softness is important, the maximum tensile strength which the metal should have is usually specified.

For the best pipe and boiler work, steel is generally made by the open-hearth process, and its composition lies within the following percentage limits: Combined carbon, 0.10 to 0.20; silicon, 0.005 to 0.010; sulphur, 0.015 to 0.045; phosphorus, 0.015 to 0.030; manganese, 0.30 to 0.50; iron oxide, 0.10 to 0.30; pure iron, 98.5 to 99.5. Tensile strength from 50 000 to 65 000 pounds per square inch.

Of these constituents, carbon and silicon affect the hardness, ductility, and tensile strength; sulphur produces "red-shortness," or interference with welding and rolling; phosphorus produces "cold-shortness," brittleness under sudden shock, and various other undesirable properties; manganese counteracts to some extent the influences of sulphur and phosphorus and causes the metal to aggregate in finer crystals, thereby increasing its elastic limit and ultimate strength.

Until within a very few years, manganese was regarded as a beneficial ingredient and was always added to the molten iron in making mild steel. Recently, however, it has been viewed as the principal cause of the rapid corrosion of soft steel under ordinary conditions of use, and this has led to a further development of the open-hearth process whereby nearly pure iron is produced without adding manganese, and also without much additional cost. This new material has been named "ingot iron," to distinguish it from steel, and a long description of it is given in *Engineering News* of January 6, 1910, pages 6–8 and 16, from which the following brief abstract was prepared.

Ingot Iron. The metallic product called "ingot iron" is made in an open hearth, like mild steel, and differs from the latter in having its contents of carbon, silicon, and manganese reduced to small fractions of the amounts found in ordinary soft steel. Its chemical composition is practically the same as that of the purest commercial wrought iron, and it contains much less impurities than common wrought iron. A typical analysis is as follows: Carbon, 0.02; silicon, trace; sulphur, 0.02; phosphorus, trace; manganese, 0.01; oxide of iron, 0.03; pure iron, 99.92 per cent.

Its tensile strength is from 47 000 to 50 000 pounds per square inch, and it has a remarkably high ductility. Its most interesting quality, however, is an apparently high resistance to corrosion.

The manufacture of this metal was evolved by the American Rolling Mill Company, of Middletown, Ohio, in consequence of the demand for an iron that would not corrode as quickly as ordinary soft steel, and in deference to the opinion expressed lately in numerous quarters that the rapid corrosion of steel is largely due to the presence of manganese. The main features of the process are the long exposure of the molten metal to a temperature of about 1677° Cent., and the addition of small amounts of ferro-silicon and aluminum just before pouring to facilitate the removal of oxygen and other gases from the liquid. It is claimed by the makers that with proper care uniform results are obtained.

With respect to corrosion, the only comparative tests thus far recorded were made with sulphuric acid, and these indicate that the resistance of ingot iron is from 20 to 40 times that of wrought iron, and from 40 to 60 times that of soft steel. There are, however, many uncertainties in such tests, and hence time alone will demonstrate its slow rusting properties. Should these be such as to be only twice the life of structures made from the best soft steel, the new process will rank as the most important innovation in the metallurgy of iron.

Difference in Composition of Wrought Iron and Mild Steel. On comparing the chemical analyses of commercial wrought iron and mild steel, little difference in composition is apparent except in respect to slag and manganese. In steel and ingot iron there is little or no slag, while in wrought iron the percentage of manganese is usually much lower than in steel. There is also little difference in the usual physical properties of the two substances when the compositions are nearly alike. In regard to durability or corrosion, however, the general opinion now seems to be that wrought iron is far superior to mild steel.

Difference in Rate of Corrosion. The difference between the rates of corrosion of wrought iron and steel, as given by numerous authorities, varies greatly. This may be due to the dissimilarity of either the forces tending to produce rust, or the composition of the two metals in the observed cases; but from the

evidence now available, it seems that under like surroundings comparatively small differences in chemical composition are able to produce relatively large differences in the rate of corrosion. The observations and tests heretofore made embrace many different conditions of exposure, such as waters and soils heavily charged with various mineral and organic acids, bases, and salts, different corrosive gases, etc.; but as a recital of all these results is here impracticable, only those cases will be considered which deal with the conveyance of potable water and the burial of pipes in the earth usually found in streets, roads, forests, and fields.

ANCIENT SAMPLES OF WROUGHT IRON. To indicate in striking manner the actual differences in rate of corrosion of samples of old wrought iron and mild steel of very recent production, a few facts may be cited that properly belong in the history of iron.

So far as the writer has been able to ascertain, the oldest specimen of wrought iron in the world is now preserved in the British Museum, along with the details of its discovery. It was removed in 1838 by Col. Howard Vyse and Mr. J. R. Hill from an inner mortar joint of the stonework near the mouth of the southern narrow air channel of the great pyramid of Cheops at Gizeh, near Memphis in lower Egypt. Judging from its position and size, it is a portion of a mason's tool broken off accidentally and left in the joint when the structure was in process of construction. According to the surmises of archeologists, this pyramid was built about 3000 years B.C., so that the fragment was presumably over 4800 years old when discovered.

This specimen of iron is about 4 inches long by 2 inches wide and $\frac{1}{8}$ inch thick. It exhibits the marks of some corrosion, but was evidently protected to some extent by the mortar, of whose composition nothing definite is recorded except that it was probably calcareous and more or less permeable to air. An analysis of a small quantity of the metal showed that it was evidently a tough wrought iron.

In 1870 Mr. G. Belzoni found in an excavation in the soil underneath a sphinx at Karnak, near Thebes in upper Egypt, a part of a wrought-iron sickle. He and other archeologists believe that this specimen must have been left in the ground long before the Persian invasion in the sixth century B.C. It was quite rusty when exhumed,

but, on being cleaned, plenty of sound metal was left to exhibit clearly its character and the marks of forging. No other definite age has been assigned to this interesting object.

It may also be stated that many other specimens of ancient wrought iron have been found in the numerous excavations made in Egypt, and are now preserved in various Egyptian and European museums. They are all of the utmost interest, as the ruins of that land are generally regarded as the oldest relics of the human race.

In 1846 and later years, Layard made his famous excavations in ancient Assyria and Chaldea, at the sites of the old cities of Babylon and Nineveh. At the former he found only a few wrought-iron finger rings, but in the latter many iron objects, such as daggers, swords, shields, spear and arrow heads, were brought to light. At Calah, he exhumed a large quantity of iron armor scales from 2 to 3 inches in length, as well as some iron helmets. It may be noted that most of the objects were very rusty when discovered, and that some fell to pieces soon after they were exposed to the air, so that only a few of them could be saved and placed in the British Museum. The period in which they were made is estimated as being between 1500 and 2000 years B.C.

Extensive French excavations of an ancient Assyrian palace at Khorsabad were also made in 1866 by Victor Place. Here a great collection of rough implements or billets of wrought iron was found in a buried chamber 16.4 feet long, 8.5 feet wide, and 4.6 feet high, the weight of the metal being about 160 tons. Unfortunately, the most of this collection was lost by shipwreck in the course of transportation to Paris. These excavations also disclosed a number of iron rings and staples still attached to a long wall, links of chains, bits for horses, etc. The chemical analysis of samples of all this metal showed that it was good wrought iron. Its age is believed to date from 1200 to 1500 years B.C.

In his excavations of ancient Troy and Mycenæ in Asia Minor and Greece respectively, during the period 1870–90, Schliemann found a number of wrought-iron objects, such as keys and knives, far below the surface of the ground, and which were still in a relatively good state of preservation. One of these specimens was found in the fourth distinct stratum of Trojan ruins below the surface, or the one following the city which Homer made famous.

Schliemann estimated that the latter was destroyed by the Greeks from 1400 to 1500 years B.C., while Gladstone considered that the event took place about 1307 B.C. The specimens of iron found at Mycenæ are regarded by Schliemann as dating from about 500 B.C.

Returning to Egypt, a very interesting fragment of wrought iron was found early in 1880 at Alexandria under the base of the obelisk which is now standing in Central Park in the city of New York. This fragment was discovered when the monolith was lifted up preparatory to removal, and it was exhibited at a meeting of the American Institute of Mining Engineers on February 17, 1880. On being analyzed it was found to have the following percentage composition: Carbon, 0.521; silicon, 0.017; sulphur, 0.009; phosphorus, 0.048; manganese, 0.116; nickel, cobalt, and copper together, 0.181; lime and slag, 0.370; pure iron, 98.738; total, 100.00 per cent. Tested by tension, its strength was 54 500 pounds per square inch, with an elongation of 14 per cent., thus showing that the metal was of good quality. Its age is conjectured to be about two thousand years.

At the mosque of Kuttub Shah, at Delhi, India, there is still standing a wrought-iron column which is described by Col. A. Cunningham in the archeological report to the government of India for 1861–2 as follows:

"The Delhi pillar is a solid shaft upwards of 16 inches in diameter and about 50 feet high. . . . Its height above ground is 22 feet, consisting of 3.5 feet roughly cylindrical lower portion, 15.0 feet smooth shaft, and 3.5 feet ornamental capital. It extends underground considerably further than above ground, as a recent excavation was carried down to 26 feet without reaching the foundation on which it rests. The lower diameter of the shaft is 16.4 inches and the upper diameter is 12.05 inches. It contains about 80 cubic feet of metal and weighs upwards of 17 tons."

An inscription on this column has led some antiquarians to think that it was erected in the third or fourth century of our own era, but others have construed the language to indicate that it was made about 900 years B.C. A small sample of the metal was analyzed by Dr. Percy, the eminent English metallurgist, who declared it to be soft wrought iron. The column is entirely free from corrosion, and many who have examined it closely in recent years have ex-

pressed the opinion that, on its completion, it must have been subjected to a process similar to that invented a few decades ago by Messrs. Bower and Barff.

Colonel Pearse, of the Indian army, examined numerous tumuli or sepulchers in India, and found therein many ancient iron and steel tools which are supposed to have been made at least 1500 years B.C. Iron beams have also been found in a number of old Indian temples.

Several objects of wrought iron were found in ancient Etruscan tombs at Cervetri, Perusia, Vulci, and Cortona, in Italy. In 1823 Avvolta discovered a grave at Corneto which led to finding, near by, a large cemetery of the old Tarquins. He states that on excavating a portion of this cemetery he found several graves containing iron spear heads and portions of iron armor, but that these objects usually began to crumble soon after being exposed. Dennis made similar observations at Vulci. Many of the objects thus found are now preserved in various Roman museums.

It may also be noted in this connection that on August 21, 1910, the Associated Press dispatches of New York contained an account of the newest discovery made by Professor Dall' Ossa in the excavation of an ancient necropolis near Civita Castellana in Italy. This locality is rich in remains of Etruscan and other prehistoric civilizations. Two tombs of Amazons were found, each of which contained not only the human female skeleton, but also the remains of a war chariot and yoke decorated with bronze and iron, as well as many iron pins and a dagger. From the jewelry and pottery likewise found therein, the discoverer believes that these tombs date from at least the eighth century B.C. Special mention is made in the account that much dampness and earth had penetrated into these sepulchers, but it is evident that their action did not cause the iron to disappear completely after so long a time.

Passing to the western hemisphere for very old specimens, it is stated that in excavating some of the ancient artificial mounds in Ohio, a variety of wrought-iron objects were found in a fair state of preservation. No definite period has yet been assigned to the construction of these mounds, which have been in existence longer than the survival of any reliable tradition relating to them among the Indians.

For samples of iron and steel made since the beginning of our own era, and which have withstood the effects of centuries of burial in the ground, we need only refer to the catalogues of the large museums of the principal cities of Europe. In these will be found many specimens of iron tools and weapons made by the Romans and later by the so-called "barbarian" inhabitants of European countries. Numerous iron relics of Middle Ages are also preserved therein, as well as specimens of more recent production.

In some of the museums of the United States may be found a variety of wrought-iron objects, dating from the Indian and Revolutionary wars, that were excavated from the ground after burial for a century or more. Unfortunately such comparatively modern relics are of little popular interest, and hence no concerted effort has been made for their preservation. This remark is also applicable to specimens of wrought iron and steel placed in the ground only about fifty years ago.

The foregoing few citations will suffice to show that apparently unprotected wrought iron and steel of certain indefinite chemical composition has been able to withstand the corrosion induced by burial in the soil for a great many years, and even centuries in some cases; and in contrast thereto we have the evidence of many recent observations and experiments that the soft steel which has taken the place of wrought iron for the past thirty years is far less durable under the same conditions of exposure to corroding influences. To describe these experiments would require much more time than is now available, especially as their results are doubtless familiar to all present.

It may be urged that in most, if not all, of the recorded cases of exhumation of wrought-iron objects, after long burial, the metal was effectively protected by being excluded from exposure to air, water, and various acids. This may be true to a limited extent, but in view of the difficulty of attaining such exclusion artificially for long periods of time by means of cements, mortars, and natural building materials, it is reasonable to assume that for the greater portion of their imprisonment these iron objects came into occasional contact with at least small quantities of oxygen, moisture, and carbonic acid, all of which are usually present in soils capable

of supporting vegetation. The conclusion therefore follows that the apparent resistance to corrosion in these cases is due to either some peculiar mode of treating the surface of the metal, or to some peculiarity of chemical composition. In either event, a thorough knowledge of the facts would be of immense value.

As the matter now stands, little will be gained by comparing chemical analyses, owing to differences of method in carrying out the same, and also to the fact that small variations in the amount of impurities contained in the samples often seem to exert a powerful influence on the degree of resistance to corrosion. If, however, the analyses were all made by the same method and care, the effect of each added quantity of impurity might be ascertained, so that the proper composition of a rust-resistant iron or soft steel could be prescribed in a specification. Under present conditions this cannot be done with much certainty of securing the desired result.

The statement has often been made that the superior resistance to corrosion exhibited by some brands of wrought iron is due to the small percentage of slag and cinder or iron oxide always found therein. Microscopical examination, however, does not justify this conclusion, as these impurities are usually found to lie in definite streaks or lines in the metal; neither is there any evidence to show that the fibers of wrought iron are enclosed by cinder or slag. On the other hand, many impure wrought irons are not at all resistant to corrosion, so that the admixture of the impurities mentioned is by no means a safeguard against serious damage by rust.

The latest view on this subject is that the purer the iron the less the tendency to the dangerous pitting or localized corrosion which is so often exhibited in very impure wrought iron and carelessly made steel. It is based on many observations of the much greater durability of puddled wrought iron over soft steel under the same condition of exposure, and also on the new electrolytic theory of corrosion, as advanced by Messrs. W. R. Whitney, A. S. Cushman, and W. H. Walker. It has also been adopted by a few manufacturers in our country, who have succeeded in developing the open-hearth process until they were able to produce in regular practice and without undue extra cost, a metal which is 99.94 per cent. pure iron, and which exhibits far more resistance to corrosion, under accelerated tests, than the best quality of soft steel.

THEORIES OF CORROSION. In their newest treatises on the corrosion of iron and steel, published this year, Messrs. A. S. Cushman, H. A. Gardner, and Alfred Sang state that there are now three well-recognized theories to account for the corrosion of iron. These theories overlap to some extent, but involve distinctly different reactions. They are called the carbonic acid, the hydrogen peroxide, and the electrolytic theories.

The first theory has been under consideration for more than forty years, and is based on the cyclical action of three factors, viz., an acid, water, and oxygen. Rusting is always started by an acid, and even the weak carbonic acid, which is so widely distributed in nature, is strong enough for the purpose. The acid changes a portion of the pure metal to a ferrous salt with the evolution of hydrogen. Water and oxygen now act upon the ferrous salt so as to form ferric hydroxide and liberate the acid, which attacks another portion of the iron; and so on indefinitely until the supply of oxygen, water, or iron gives out. If the acid is not present, the iron will not rust, nor will it do so in the absence of either of the two other factors. Recently, however, experimental evidence has been given to show that rusting takes place rapidly in the presence of water and oxygen alone.

The second, or hydrogen peroxide theory, was advanced by Traube more than twenty years ago, but has not been extensively followed. It assumes the presence of only iron, oxygen, and water. The oxygen is assumed to act in two portions, one of which attacks the iron and forms unstable ferrous oxide, while the other combines with the water and forms hydrogen peroxide. These two products then combine to form stable ferric hydroxide, leaving an excess of hydrogen peroxide to attack a new quantity of ferrous oxide. The theory has been strongly criticised within the past six years as not being in accordance with careful experimental tests.

The third, or electrolytic theory, appears to have had its inception in the researches of Dr. W. R. Whitney, published in the Journal of the American Chemical Society for 1903 (Vol. XXV, p. 394). It was then developed so skillfully by Dr. A. S. Cushman, of Washington, and Prof. W. H. Walker, of Boston, that it has now been generally adopted by chemists in this country and abroad. It rests on the modern principle of physical chemistry, that all

reactions taking place in the wet way are attended with certain readjustments of the electrical states of the reacting ions; or, expressed in another way, when two substances of different polarity are immersed in a suitable liquid medium containing free ions of matter, an electric current is set up, and the substance from which the current flows tends to dissolve. It thus assumes that before iron can oxidize in the wet way, it must first pass into solution as ferrous ions.

Cushman further explains the process of rusting as follows:

"When a strip of metallic iron is placed in a solution of copper sulphate, iron passes into solution and copper is deposited, this change being accompanied by a transfer of electrical charge from the ions of copper to those of iron. Hydrogen acts as a metal and is electrolytically classed with copper in relation to iron. If, therefore, we immerse a strip of iron in a solution containing hydrogen ions, an exactly similar reaction will take place; that is to say, iron will go into solution and hydrogen will pass from the electrically charged or ionic state to the atomic or gaseous condition. In such a system the solution of the iron, and, therefore, its subsequent oxidation, must be accompanied by a separation or setting free of hydrogen. It is very well known that solutions of ferrous salts as well as freshly precipitated ferrous hydroxide, are rapidly oxidized by the free oxygen of the air to the ferric condition, so that if the electrolytic theory can account for the original solution of the iron, the explanation of rusting becomes exceedingly simple."

The theory also rests on the laboratory demonstration that a small proportion of iron can pass into solution in ionic form in pure water, and that the latter always contains some free hydrogen ions; hence it follows that neither oxygen nor carbonic acid is needed to assist the action of pure water in starting the formation of rust. The hydrogen ions seem to act as an exciter in starting the reaction by creating a galvanic current, which is carried from one point on the iron to the water by the escaping iron ions, and from the water back again to the iron by the separating hydrogen ions, this process being continued indefinitely. Furthermore, if the metal contains impurities, like manganese, that are electrically positive to the iron, this galvanic action is intensified. Much more might be said on the subject, but as the time therefor is not now available, such additional explanations must be sought in Dr. Cushman's new book.

The corrosion of iron in water has also been discussed in a very instructive manner by Mr. Geo. W. Fuller, in the issue of *Engineering Record* for April 23, 1910; and as this paper contains many useful data, the following brief abstracts therefrom may be of interest.

Iron will corrode more rapidly in waters containing dissolved oxygen and compounds of an acid nature, even though very weak, such as carbonic acid. All surface, filtered, and ground waters contain more or less dissolved oxygen and carbonic acid, besides a variety of other substances of both mineral and organic nature. The oxygen is generally absorbed from the atmosphere either above or below the surface of the ground, and in the case of surface waters a part of the oxygen is sometimes supplied by certain aquatic plants. The quantity of oxygen thus held in solution varies with the temperature, the degree of organic impurity, and the agitation of the water. When fully saturated, the range in pure water is from 14.70 parts of oxygen by weight per million at 0° Cent. to 7.60 parts at 30° Cent., so that the quantity changes considerably in the different seasons. It must also be remembered that in the case of polluted water the bacteria often consume a large proportion of this dissolved oxygen in their action on carbonaceous organic matter, and liberate a corresponding quantity of carbonic acid which goes into solution.

From numerous analyses of the water in various large rivers, it appears that in winter the quantity of dissolved oxygen is from 9 to 12 parts per million, while in summer it is from 5.6 to 7.5 parts. Ground waters, on the other hand, usually contain much less oxygen in solution than the surface waters, presumably because the bacteria in the porous earth, through which the water passes downward to the plane of saturation in the subsoil, abstract a large percentage of this gas. Available analyses show a wide range in this respect, the variation being from nearly the aforesaid saturation limits to only 10 per cent. thereof, with an average of about 50 per cent.

At already stated, free carbonic acid is derived in part from the air, but mostly from bacterial action on the organic matter contained in either the soil or the water. Surface waters usually hold in solution much less carbonic acid than ground waters, the

contents of the former being from a very minute quantity to 15 parts by weight per million, while the latter may contain from 3 to 25 parts. In some mineral spring waters the proportion is very much higher, even attaining the stage of effervescence. The presence of this gas increases the solvent powers of the water, and enables it to dissolve carbonate of lime and magnesia quite freely. One gallon of pure water will only dissolve two or three grains of these carbonates, but when it becomes strongly charged with carbonic acid, it may dissolve twenty or more grains.

Natural waters also often contain certain other acids and compounds of organic origin which tend to promote the corrosion of iron. Such acids and compounds are mostly found in swamps, moors, and peat bogs, but, unfortunately, little is yet known of their action on iron and steel; in general, however, it may be regarded as detrimental by stimulating or favoring the passage of electric currents through the water. The same remark likewise applies to organic compounds derived from other sources, such as dead animals, manures, decaying garbage, etc.

Solutions of the alkalies and alkaline earths, like soda, potash, ammonia, lime, magnesia, baryta, and silica, do not cause iron to corrode directly, but the neutral salts of these bases seems to affect the metal unfavorably under some conditions. Attention to this matter has recently been called by the extensive external and internal corrosion of the steel pipes of the Coolgardie water works in Western Australia, which were completed only in 1903. A good account of this trouble is given in *Engineering Record* of May 21, 1910, and we learn therefrom that the pipe is buried for many miles in a soil containing considerable quantities of soluble salts, which give rise to corrosion when moisture is present; also that the water conveyed in the pipe is somewhat saline in character.

According to the published analyses, this water contains 25.5 parts per 100 000 of sodium chloride, 5.5 of magnesium chloride, 2.3 of calcium sulphate, 1.7 of calcium and magnesium carbonates, 0.8 of free and 1.2 of combined carbonic acid, together with small quantities of silica and iron oxide. It was found by experiment that it rusted steel much more vigorously than did London water, which contained 8.9 parts of combined carbonic acid. When the Coolgardie water was well aërated and allowed to flow slowly for

a week over a sample of the steel plate used in making the pipe, the loss of metal by corrosion was 2.38 milligrams per square centimeter of surface, while with the London water it was 1.72 milligrams. These figures correspond respectively to 0.004874 and 0.003522 pound per square foot.

It may also be remarked that the committee who investigated this case consisted of Sir William Ramsay, Mr. Geo. W. Deacon, and Mr. Otto Helmer. Their study of the subject led them to the conclusion that the essential cause of the corrosive action of all waters on steel and iron is the dissolved oxygen which they contain, and which excites an electrical action. By the removal of this oxygen, they found that this electrical action ceases, and the rate of corrosion is enormously reduced. As the most economical method of removing the dissolved air or oxygen, they recommend the spraying of the water into a vacuum chamber and then adding about 3 grains of lime per gallon. For preventing external corrosion, they advised scraping off the old asphaltic coating and applying a new one composed of bitumen and tar; then bedding the pipe on a cradle of lime concrete on the bottom of the trench, and covering the remainder of the pipe surface with a layer of slaked lime 0.5-inch thick.

PROTECTIVE COATINGS. The subject of protective coatings for thin iron and steel pipes is fully as complicated as that of corrosion. A great variety of different processes and materials have been tried and more or less enthusiastically advocated, but inasmuch as practice in this respect is far from being settled, it is fair to conclude that none of them has withstood successfully the crucial test of time. It is understood that this remark applies only to those processes which are not prohibitory by their expensiveness.

The protective methods are both metallurgical and mechanical in character. In the former the aim is to alloy the iron with one or more other metals, whereby the product will not corrode under certain definite exposures; while in the latter, only the surface of the metal is to be covered completely with some other element or complex substance that will not undergo chemical or physical alteration within the same range of exposure. Freedom from corrosion in the second method, therefore, depends wholly on preserving the integrity of the applied coating during the various

manipulations of the pipe, or in thoroughly repairing all incidental damage before the pipe is finally buried.

Various alloys of iron have been made which possess excellent rust-resisting properties, combined with fairly high tensile strength and good malleability, but, unfortunately, their cost is still too great to render them available in competition with cast-iron pipes. In the present state of metallurgical art, it is extremely difficult to devise a formula for such an alloy which will satisfy all the various requirements, as it is well known that small variations in the quantity of certain additions to pure iron affect greatly the physical properties of the alloy; hence it is very probable that a successful composition can be developed only by patient trial. In the writer's opinion, the most satisfactory results will be attained in this direction of experimental research.

Mechanical coatings with other metals, such as zinc, tin, copper, nickel, etc., are all too expensive on a large scale, and are easily damaged in the transportation and handling of the pipe in the field; neither has a practicable method of repairing such damage yet been devised. The same remark also applies to coatings with stable ferric oxide, or magnetic oxide of iron, as produced by the Bower-Barff process. Enamels made of various pulverized minerals and fused upon the surface of the iron or steel at high temperatures are generally too brittle and open to the objections of impracticability of repair in the field. This line of experimentation, however, is an attractive one, and the writer has learned that an economical process of this nature involving the use of pulverized clay and moderate temperatures is being carefully investigated by one of our leading contractors.

Next in order is the japanning process, which was first applied to one half of the Rochester conduit of 1894–5, and soon thereafter to a number of other steel pipe lines. There can be no doubt from all the experience thus gained that if the process is properly conducted an excellent protection to soft steel buried in the ground will be secured. Its cost, however, has militated strongly against its more general adoption, and the small thickness of the resulting film has been used as a potent argument in favor of thicker and cheaper bituminous coatings of alleged great durability.

Varnishes of different kinds of asphalt and coal-tar pitch, in

combination with a variety of other substances, have been used for many years, the usual method being to heat the mixture to about 320° Fahr. to render it liquid, and then to dip the pipe therein after having been thoroughly cleaned and heated to nearly the same temperature. In some instances the pipe has been dipped twice in this manner, with the expectation of remedying any accidental defects in the first coating and producing a thicker adherent film, but there is no good evidence that this procedure increases the durability of the pipe materially, as all such coatings are unavoidably injured while making the field joints.

The principal objection to these hot bituminous varnishes is the uncertainty of obtaining a mixture of uniform quality. This applies not only to the mixture itself in its heated state, during which a change takes place by the escape of volatile compounds, but also to the several constituents as delivered by manufacturers. In most cases the chemical composition of the materials varies greatly from time to time, due to changes of source of supply and mode of preparation. It therefore follows that each shipment should be examined by an expert chemist in order to maintain a proper standard of quality, and that all losses resulting from keeping the mixture at a high temperature shall be compensated in satisfactory manner. In practice very little is done in these directions owing to the expense of scientific investigation.

In regard to paints and varnishes that are applied at the prevailing temperature of the atmosphere, the writer ventures to offer but few remarks. From numerous experiments and observations during the past thirty-five years, with many different kinds of paint and varnish on small pieces of iron and steel buried for long periods of time in various soils, he has not succeeded in finding one that protected the metal satisfactorily from corrosion; but it should also be noted that not more than two thin coats had been put on the specimens. For repairing accidental abrasions of pipe coatings and defective spots found on exposing a pipe by excavation, he prefers to apply a hot bituminous material, such as the compound called " mineral rubber," or a hot mixture of coal-tar pitch with a small percentage of pure linseed oil. The reason for this preference is essentially because the coating hardens quickly, thus allowing the excavation to be refilled without much delay.

STIFFNESS OF THIN PIPES. In designing a relatively thin metallic conduit, due attention must be given to the external forces acting upon it, as well as to the internal water pressures. Under usual conditions, the external forces are the pressure of the atmosphere, the weight of more or less of the backfill, and the support of the pipe at the bottom and sides of the trench. Of these, only the first is known with reasonable certainty, while the magnitude and direction of the others depend so much on variable circumstances that it becomes necessary to resort to assumptions.

If the backfill is either a soft and flowing mud, or a perfectly dry sand, a uniformly distributed external pressure acting in radial directions may be assumed; but as these materials are seldom available for the purpose, both the weight of that portion of the backfill which is carried directly by the pipe, and the manner in which the loaded pipe rests upon the bottom of the trench, will usually vary within wide limits. The result is generally a very appreciable deformation of the circular cross-section of the empty pipe, so as to make the section elliptical, the longer diameter being horizontal.

Not many observations of this kind have been published, and hence it is difficult to determine a reliable ratio of deformation for different diameters, thicknesses, and depth of backfill; but from the data collected by the writer relating to empty steel pipes from 3 to 6 feet in diameter and from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick, it appears that when the depth of well-compacted earthen backfill over the top of the pipe is from 6 to 8 feet, the normal vertical diameter may be reduced as much as 10 per cent. These data are not sufficient to determine either the magnitude of the external load or its mode of distribution on the upper surface of the pipe, nor do they demonstrate that a greater deformation would not ensue if the backfilled material were heavier and looser, or contained more moisture, so as to reduce arch action and throw more weight upon the empty pipe.

In the cases mentioned, the bottoms of the trenches had been carefully graded, and the finest available material had been packed under the lower quarters of the pipe to afford a fairly uniform support. Obviously much depends on this feature, as otherwise the supporting reaction would tend to become concentrated at a

number of isolated points on the bottom, whereby the deformation would be increased. The same thing would also happen if large stones or bowlders were mixed with the earthen backfill over the pipe. Doubtless there are many places in every conduit where the load and support are at times far from being uniformly distributed, and when these forces exceed certain limits, the pipe will be in danger of collapsing if the internal water pressure is removed.

A recent discussion of this subject by Prof. A. N. Talbot will be found in Bulletin No. 22, University of Illinois Engineering Experiment Station, published April 29, 1908. Formulas for the largest bending moment and the corresponding stress in the outermost fibers of a thin elastic ring are there given for both concentrated and uniformly distributed vertical and horizontal loads; and by applying these formulas to the case of large steel pipes in which the metal has an elastic limit of 30 000 pounds per square inch, it will be found that when the depth of backfill is from 5 to 6 feet, and the weight thereof is assumed to be distributed vertically and uniformly over the surface of the pipe, the maximum fiber stress will approach closely to said elastic limit; and when the load is concentrated along the top and bottom lines of the pipe, the stress will generally exceed said limit.

It is, however, fair to consider that the earth which is in contact with the sides of the pipe will offer some resistance to displacement when the pipe begins to flatten, so that the aforesaid bending moment and fiber stress will doubtless be reduced somewhat; but as we have no trustworthy experimental data regarding the magnitude of such lateral resistances under various conditions of moisture in the material, it will be prudent to assume that depths of backfill of more than 6 or 8 feet are unsafe for thin pipes of the sizes and thicknesses mentioned above. In cases where this depth must necessarily be greater, provision should accordingly be made for giving the pipe an adequate stiffness, either by increasing the thickness of the plate, or by applying stiffening rings of angle-iron, or by bedding it more or less completely in concrete. The same procedure is also required where the pipe passes under railway tracks, or the shallow backfill is subjected to unusual loads.

The foregoing considerations indicate that an empty pipe of large diameter and small thickness is capable of withstanding only

moderate external loads of backfill without becoming seriously deformed; hence it is necessary to guard against the application of any additional loads, and especially against the formation of a vacuum in any part of such a conduit when the water is drawn off, as the external pressure thus developed may easily be much greater than that of many feet of earthen backfill. This action is to be feared most in highly porous and soft ground, but as all drained soil contains a large percentage of voids through which air can flow without great resistance, it should be assumed that atmospheric pressure against the exterior surface of the pipe is always in operation, and that it should constantly be balanced by an equal internal pressure.

Equilibrium in this respect exists naturally so long as both ends of the pipe are open to the atmosphere, either directly or by means of the water which fills the conduit. If, however, an orifice in some deep depression in the line is opened, through which more water will escape during a short period of time than the conduit can deliver with its available hydraulic grade, the pressure of the atmosphere at such orifice will be expended in the effort to maintain the continuity of the columns of water on each side of the orifice, thereby reducing the internal pressure at the adjacent higher elevations in the conduit. The same action occurs when a stop-valve in the conduit is closed and the water in the downstream section is permitted to escape.

To maintain the equilibrium mentioned in a collapsible pipe under all circumstances, it is therefore necessary to provide it with air-inlet valves at every main stop-gate, and also at every considerable summit. These inlet valves must have sufficient capacity to admit the required volume of air at nearly atmospheric pressure. To compensate for the resistance to free circulation of air in the ground, it may be assumed that the active pressure of the air against the exterior surface of the pipe is about four fifths of the barometric pressure, thus leaving a difference of 3 pounds per square inch available for forcing the air through the valve into the pipe whenever it may be required. In some cases the difference in pressure used to compute the dimensions of the air-inlet valves has been somewhat more than 3 pounds per square inch, but in view of all the uncertainties involved, it seems preferable to err on the safe side.

DETAILS OF CONSTRUCTION, ETC. This paper has already greatly exceeded its contemplated limits, and hence further reference to details of construction must be omitted. It may be stated, however, that steel plates are now made into large pipes by three methods, viz., riveting, the use of lock bars, and welding. A fourth method of manufacture directly from the hot ingot, by the Mannesmann process of tube drawing, was also promised fifteen or more years ago, but for some reason it has hitherto been applied only to the fabrication of pipes not more than 12 inches in diameter. The welding process, on the other hand, has been developed in Germany to such extent as to admit of the production of seamless pipes 10 feet in diameter, and up to 150 feet in length. This operation, however, requires much more time and more costly apparatus than either of the first two methods, and hence it has not yet been adopted for large water conduits in the United States.

Riveted pipes are not patented, and do not involve great outlays for manufacturing plant, but they entail much expense for labor and have the disadvantage that their inner surface is roughened by many rivet heads and that a considerable portion of the metal at the seams is cut away by the rivet holes. The efficiency of a properly proportioned double-riveted seam is only about 70 per cent., whereas well-made lock-bar joints and welded seams exhibit in regular practice the same tensile strength as the adjacent plate metal. In regard to price per foot, the standard of comparison is obviously the cost of riveted pipe under proper competition. At present market prices of labor and materials, contractors bid about 4.0 cents per pound for soft steel pipe, including bituminous coating, moderate transportation, and jointing in the trench.

Under the same conditions, cast-iron pipe would cost about 1.3 cents per pound, plus the cost of placing and jointing. The diameter of the pipe and the water pressure now become important factors. Owing to its greater roughness of surface, it is found that the riveted pipe should have a diameter about 8 per cent. larger than that of the cast-iron pipe to give the same discharge on the given hydraulic grade. In the case of lock-bar and welded pipes, however, no appreciable increase of diameter is required. The internal water pressure determines largely the thickness of the metal, as it brings the tensile strength thereof into action. The

physical tests of soft steel and good cast iron show that these materials have ultimate tensile strengths of about 60 000 pounds and 16 500 pounds per square inch respectively, thus giving a ratio of 3.6 to 1.0, but general experience has established the practice of allowing the stress in the metal, due to the water pressure, to be only one fifth of the figures mentioned.

It has also been learned that the normal pressure in a pipe is considerably increased for short periods of time when the motion of the water is rapidly stopped by the closing of a main valve in the line. The magnitude of this increase is difficult to determine, as it depends greatly on the time taken to close the valve. From such observations on large conduits as have come to the writer's notice, this increase is about one half of the static pressure at the point under consideration; hence in computing the thickness of the pipe, at least 1.5 times the static pressure should be used in the formula. Furthermore, to compensate for unavoidable differences in thickness of shell and strength of metal, as well as to allow for a gradual reduction of thickness by corrosion, a certain arbitrary addition is usually made, which is about $\frac{1}{4}$ inch for cast-iron pipes and $\frac{1}{16}$ inch for steel pipes.

The formulas for the weights and costs of such pipes per linear foot are rather complicated, so that a comparison of results is not easily made. It must also be remembered that the costs will vary from time to time with the market prices of materials, labor, and transportation. Under the conditions stated above, however, and the further assumption that the static water pressure is 100 pounds per square inch, the writer has deduced two simple formulas for the approximate costs of large riveted-steel and cast-iron pipes, as follows:

1. For steel pipe, $y_1 = 0.4125.d^2$;

2. For cast-iron pipe, $y_2 = 19 + d(0.4845d - 0.851)$; in which y is the cost of the pipe in cents per linear foot exclusive of trenching, and d is the nominal diameter of the pipe in inches. The value of d to be used in these expressions is that of the cast-iron pipe, although the actual diameter of the steel pipe is 8 per cent. larger. It should also be noted that the expressions apply to diameters ranging from 2 to 6 feet and the aforesaid pressure.

These formulas indicate that the cost of steel pipe is less than

that of cast-iron pipe for all diameters, and that the difference in cost in cents per linear foot can be expressed by: $y_2 - y_1 = 19 + d(0.072d - 0.851)$. Applying this to the case of the Rochester conduit, where d was 36 inches, we have: $y_2 - y_1 = 81.7$ cents per foot, whereas the actual difference was in the vicinity of 50 cents, with rather light cast-iron pipe. With more conservative thicknesses for the latter and due allowance for overweight and loss by breakage it is probable that the difference would have been at least 60 cents per foot. The circumstances in this case, however, were of unusual character, as the lowest bidder declined to enter into contract, and the work was subsequently awarded to and performed by the next lowest bidder at a considerably larger cost to the city.

It will be noticed that the ratio $\frac{y_2 - y_1}{y_2}$ cannot be expressed in simple terms, and it is also evident that the life of a steel pipe is still invested with much uncertainty; hence it is not practicable to draw a general conclusion with respect to the economic advantage of such a conduit. If we assume the life of steel and cast-iron pipes at twenty-five and fifty years respectively, it will at once follow that a steel pipe will be equivalent economically to a cast-iron pipe, if the investment of the initial difference in cost at compound interest yields a sum at the end of twenty-five years sufficient to renew the steel pipe. When the cost of renewal is the same as the original cost, and the rate of compound interest is 4 per cent., financial equivalency will occur if the initial difference in cost is three eighths of the original cost of the steel pipe; and if the interest be 6 per cent., about one fourth of the original cost will suffice.

Conclusion. In the foregoing, attention has been called mainly to objections to thin steel pipes, and little reference was made to their many advantages. On this latter subject much can be said. As already indicated, the durability of such conduits is at present the principal matter of interest, and it is to be hoped that steel makers will soon direct their efforts to the production of a metal which will exhibit a much higher resistance to corrosion than has heretofore been attained. After this is accomplished, steel pipes will be used far more extensively in water works than heretofore.

DISCUSSION.

MR. FRANCIS H. LUCE.* The speaker made it very plain that there is a great difference in the durability of wrought iron and sheet steel, but it seems to me that he has pointed out no very clear reason for that difference. I have had quite a large experience in making the comparison between wrought iron and sheet steel. For some twenty years I was engaged in the manufacture of enameled-ware kitchen utensils. Prior to 1892 we used wrought iron entirely. As the speaker stated, wrought iron is puddled and hammered and worked into a mass, while steel is practically molded, so naturally wrought iron is much more porous and of more open grain than sheet steel, which is very close and compact. Prior to 1892 we used nothing in this country for enameling for kitchen utensils, etc., but the old-fashioned charcoal wrought iron, and the enamel adhered so tenaciously to it, without the use of antimony or anything else to help it, that it was almost impossible to knock it off. I have pieces at home in my kitchen which have been in use almost constantly for many years. Ask your wives how long kitchen utensils of the present day will last, and they will tell you it depends entirely on the maid she has.

Up to 1892 there were two large manufacturers of kitchen utensils in this country, and the utensils were made under patents, and made, as I say, with charcoal iron. The patents ran out around about that time, and the manufacturers of tinware then began making enameled ware, and about that time the use of sheet steel became more general. The manufacturers of sheet steel claimed that they had perfected it to such a point that it would supersede wrought iron, and that it was just as good or better, and could be furnished for about half the price or less. Manufacturers started in using sheet steel for enameled ware, and reduced the price in proportion to the ratio of the cost of the base metal to the cost of the finished product. I think it figured somewhere around 20 or 25 per cent. The old line manufacturers found it impossible to meet the price without using sheet steel, and so they began to use it.

The people who started the use of sheet steel for this purpose

* Superintendent Woodhaven Water Supply Company, Woodhaven, N. Y.

loaded their enamel very heavily with antimony and arsenic and other substances to make it stick. The concern I was with tried to avoid that, and we experimented for a very long time and found finally that only by the interpolation of a coating of cobalt or nickel, we used nickel finally, applied a little differently from the ordinary electric coating, could we make the enamel adhere. We claimed that it adhered as well as it did on the old charcoal iron after interpolating that metal; but on applying the enamel in its raw state to the sheet steel without putting in anything between, in the same way that we applied it to the sheet iron, it would not hold at all, but would fall right off, at the least little touch or knock.

I believe that is the case with almost everything that is made that requires coating, owing to the difference in the porosity or grain between charcoal iron and steel. It used to be, if we wanted to put up leaders on our houses which would last for many years, we would put up galvanized iron ones and not tin ones. But now we put up galvanized *steel* leaders and they last only four or five years, whereas galvanized *iron* ones used to last thirty or forty. Why? Simply because the coating of zinc has not had an opportunity to go into the pores or the open grain of the base metal. Speaking from the experience I have had, I want to say that one reason that sheet steel pipes do not last anywhere near as long as the old wrought-iron pipe, is because of the lack of ability to make the coating stick. If there is no opportunity for the coating to take hold of the grain of the metal, so that you cannot coat it properly, naturally it will not last.

MR. EDWIN A. FISHER.* Some people have an idea that this new conduit, as we call it, which Mr. Kuichling has described, is rapidly going to pieces, and that it is almost time to reconstruct it, but as matter of fact the corrosion is confined to pittings, as Mr. Kuichling has stated, and the conduit, so far as its strength is concerned, is as good as ever.

We have spent on the conduit something like $8 000 to $10 000 a year. Mr. Little, the superintendent, has charge of that work. Whenever a leak is discovered, the pipe is in general uncovered each way from that point until we find no further evidence of corrosion.

* City Engineer, Rochester, N. Y.

The pipe is then scraped, as Mr. Kuichling has stated, and recoated. Last year several places were uncovered where the pipe had been recoated during the years 1902, 1903, and 1904, and no evidence of further corrosion was found in these recoated sections. Up to the present time about three miles of the conduit has been recoated out of a total of 26½ miles.

MR. WILLIAM MURDOCH.* I think an explanation of the apparently enigmatical expression as to varnish on the conduit is that the conduit was coated with pure asphalt. I was quite interested in reading that it was coated with pure asphalt. The pipes, I think, were dipped and covered with asphalt. Now, I notice that the writer who is quoted here advises that the asphaltic coating be removed, for it seems to have been a failure, and that a mixture of bitumen and tar be used instead. That would mean asphalt and tar, which is just another name for asphalt. In other words, the varnish should have tar added to it instead of pure asphalt. That is my recollection of the description of the varnish which was placed on that pipe in Australia. I think that the explanation is that instead of pure asphalt the coating should be a mixture of asphalt and tar.

MR. LEONARD METCALF.† I have been immensely interested in Mr. Kuichling's paper, which seems to me to be a very valuable contribution to our knowledge on this subject and a splendid summing up of information to date. Incidentally, as bearing upon Mr. Luce's comments, in explaining the difference in length of life by the difference in porosity of the material which makes it possible to get a coating which will adhere to the pipe, it may be interesting to call attention to what you all doubtless have observed, that in the case of nails, for instance, the old wrought-iron nails, which you have often seen in barns and old buildings, have stood up perfectly for twenty, thirty, forty, or fifty years. I have seen some older than that. There was no coating on them, and they were exposed to the rain, and yet apparently they did not rust. That is not true of the steel nails; they rust almost immediately. Take hinges, for instance, on some old structures, some of which have not been protected by paint.

* City Engineer, St. John, N. B.
† Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

They too have stood up well when made of wrought iron. Consider some of the old wrought-iron hand railings which you have seen on some of our colonial houses many years old, which apparently had no coating upon them, and yet there were no signs of rust. That would have been impossible with steel hand railings, even though coated.

MR. L. M. HASTINGS.* I have been interested in Mr. Kuichling's paper because in Cambridge we have had very much the same experience that they have had in Rochester. Our work there was done after the Rochester work had been completed, and we benefited a great deal by Mr. Kuichling's experience. We have four miles of 42-in. sheet-steel pipe, made very much on the same specifications that were used in Rochester. Of course the vital question is the durability of the steel, and that depends on the coating, and so a great deal of attention was paid to that at the time that the conduit was built in 1895. I looked at all available coatings, and it seemed to me then that the Sabin coating, which Mr. Kuichling and Professor Sabin had gotten up, was the best there was at that time.

Mr. Luce, comparing the old wrought iron and the sheet steel, has spoken of the comparative porosity of the two. That question came up in considering the matter of the application of the Sabin coating, and the matter was provided for by heating the metal. In applying the Sabin coating one essential point is that the pipe itself should be heated very hot, so that the pores of the steel will be open, and then dipped immediately in the hot mixture.

As to the actual resulting durability in Cambridge, I cannot give any very definite information, because we have not uncovered the pipe lately. But in several places I have seen portions which have been exposed, and the pipe itself, where it has not been interfered with by outside influences, or by electrolysis, has proved very durable. Even where the body of the Sabin coating has been knocked off by picks, there seems to be a thin film of coating adhering to the steel which has prevented rusting. It was very interesting to me to note that the most of the flaking occurred at the lower end of the pipe, where the varnish was probably two or three times as thick as at the top of the pipe as it was dipped in

* City Engineer, Cambridge, Mass.

coating. But even there, where the coating had flaked off, we actually found in the ground that the thin skin or film, or underskin, as you might call it, had penetrated the metal and had preserved it from corrosion

I might say in regard to the durability of steel and cast iron, and wrought iron, that at the time of the construction of the pipe, out of curiosity, and as matter of experiment, I had a number of plates of coated steel, coated iron, coated cast iron, and three sheets of uncoated metal put into the water and kept there for a year or two, just to see what the effect would be. They were very carefully weighed before they were placed in the water in Fresh Pond, our own water supply, and after fifteen months, I think it was, I pulled them out and weighed them up again. I haven't the figures with me, — they will be found in the American Society of Civil Engineers' reports,* — but I know that the general result was that there was not much difference between iron and steel in the action of the water on the plates, for the time during which the experiments were made.

I think our coating has proved very satisfactory. Of course it will not protect the pipe from electrolysis. We found that our pipes in two or three places were affected by the action of electricity, but of course that is something which no pipe will stand. We have suffered very severely from that in Cambridge, both on the cast-iron and steel pipe, but so far as the action of the soil is concerned, I believe we have had little or no difficulty from the acids in the soil. When we have had occasion to tap on to our main steel pipe line, the inside, as I remember, has shown very little deterioration; the water has not acted seriously on it.

Mr. W. C. Hawley.† I am glad Mr. Kuichling has called attention to the external forces which act upon large pipes. That is a matter which is often overlooked, and we still find in specifications occasionally that the pipes shall rest upon two or more blocks. I don't know why we should wish to concentrate the load, but it is sometimes done, and I have had very unpleasant experiences, in the last few years, with 36-in. and 42-in. pipes which have burst under such conditions.

* Transactions American Society Civil Engineers, Vol. XXXVI, p. 504.
† Chief Engineer, Pennsylvania Water Company, Wilkinsburg, Pa.

Mr. Kuichling has confined his paper to a consideration of pipes laid in ordinary soil, not in contact with salt water. It may be interesting to some members of the Association, who have salt water to contend with along the coast, to refer to the Atlantic City 30-in. steel pipe line, which was laid nine years ago. Mr. Kuichling was the consulting engineer, and we recommended to the board of water commissioners, and they concurred in our recommendation to city council, a wooden stave pipe as being preferable to either cast iron or steel. The council, however, preferred steel pipe, and it was laid. We prepared the specifications very carefully. The pipe was dipped in mineral rubber and then, in order to protect it during transportation, it was immediately stood up in a stall and covered with burlap, brushed into the hot mineral rubber just as paper is put on a wall. We expected that the burlap would rot in a few months, but it did not. However, it protected the pipe during transportation.

The pipe was delivered in February and March. The first half mile was carted out on to the salt meadow, which, fortunately, was frozen over for the first time in a great many years. The next half mile was unloaded directly from the cars on to the meadow, the weather having moderated in the meantime, and rolled from there to the pipe line. The pipe line was approaching the railroad at an angle of about 15 degrees, and I think the maximum distance of rolling the pipe was perhaps 600 or 800 ft. After the pipe was finished there was no trouble for about three years, if I remember correctly, and then in that half mile where the pipe had been rolled across the meadow a number of leaks were found, and within two years more I think something like 60 leaks were found in that section. But very few leaks were found in other parts of the four miles of pipe up to that time. Since then the leaks have gradually become general over the whole main, and I may state that to-day the pipe line has very nearly reached its limit of service. A great many holes have been filled by driving in wooden plugs, and part of the line has been encased in concrete. It seems to me that this shows that where the coating was damaged, probably by the stalks of meadow vegetation in the half mile where the pipe was rolled to the ditch, the metal was at once attacked. In the balance of the pipe it has taken longer, and it may be either

the fault of the coating or it may be some inherent trouble with the metal. It is a source of some satisfaction, however, that at the present time they are laying a 48-in. wooden stave pipe across the meadow at Atlantic City.

MR. ALLEN HAZEN.* My first experience with steel pipe was in 1897, when 8 000 ft. of 48-in. steel pipe were laid to connect the filter plant then being built with the pumping station of the Albany water works. Mr. Kuichling was consulted because he was believed to be one of the best posted men in the United States upon pipe questions. This pipe is still in service, and as far as I know has never been heard from.

The primary reason for using steel pipe is, of course, one of cost. At Springfield, Mass., for instance, a line of 42-in. pipe 12 miles long, completed a year ago on competitive bids for cast-iron and steel pipe, cost only two thirds of the low bid for cast-iron pipe. In other words, the steel pipe cost $2 where the cast-iron pipe would have cost $3. For large pipe lines that proportion perhaps indicates roughly the comparative costs that have held in the last five years.

The steel pipe at Springfield is very much stronger, more reliable, and tighter than any cast-iron pipe could be made. On the other hand, it is perhaps less durable. Of this we do not know much. Some steel pipe lines fifteen to twenty years old are still in service, in excellent order, with no apparent reason why they should not last for twenty years longer, and perhaps for an indefinite period thereafter.

More than 99 per cent. of all the material that goes into steel pipe remains without injurious or rapid corrosion. Where injurious corrosion has been found, it is a strictly local phenomenon. It occurs where there have been defects in the steel plates or in the coating. The injurious corrosion has been confined to these places, or, in other words, to a few pits, covering, as Mr. Kuichling has shown, hardly more than an infinitesimal portion of the whole surface of the plates. As the plates have been able to resist corrosion in ninety-nine and a large fraction per cent. of their whole surface, it would certainly seem that they might be perfected so as to resist corrosion in all parts.

* Civil Engineer, New York.

The trouble at the present time is that we do not know enough about the defects that cause the starting of this injurious corrosion. We want to know more about these causes, and we are going to find out about them, and we must all work together along this line.

The wrought-iron pipe used in lines laid twenty years ago and more seems clearly to have been more durable than the steel pipe that succeeded it and is used to-day. Wrought iron can still be secured at an increased price, but at a price that would not in itself prevent its use in large pipe lines. A practical objection is the limited size of plates that can be rolled from it. The largest wrought-iron plates that have been successfully rolled are much smaller than most of the plates used in steel pipe lines at the present time.

Mr. Kuichling has mentioned a new product, called "ingot iron," which is almost chemically pure iron, and which promises a great deal to the pipe business, if it can be made cheaply and rolled in sufficiently large plates.

The general system of steel pipe and wrought-iron pipe represents a more scientific, efficient, and economical use of metal than is reached in cast-iron pipe. With the improvements that are being made, it seems practically certain that it is going to replace cast-iron pipe for everything above 36 in. in diameter. For 30-in. pipe and smaller, of course, there is a field that is now held and probably will be held for a long time by cast-iron pipe.

Mr. Morris Knowles.* Pittsburg has had a number of steel pipe lines, and I will refer to a few of them briefly.

The Allegheny Main, so called, running from Montrose Pumping Station to the reservoir on the North Side, formerly the city of Allegheny, was laid in 1895–6. It is 60 in. in diameter and made of steel plate, protected with the hot applied and baked coating of A. H. Sabin. This main runs directly through the filtration works and was uncovered in five places during the building of other structures in 1905–6. The line was found to be generally in good condition as far as the exterior was concerned. We, of course, did not see the interior. The coating was in fair condition and apparently there were no pits.

* Chief Engineer, Bureau of Filtration, Pittsburg, Pa.

Since that time, however, serious defects have been located a little below the filtration works in the borough of Sharpsburg, where the line had evidently been subject to some great corrosive action, either electrolysis or soil conditions. The soil at this place was partly clay and partly slag and ashes, while that at the filtration works was sand and silt from river deposit. There were a number of places within a local area in Sharpsburg where the plate had holes completely eaten through. These were tapped out and ferrules inserted in the usual manner. Since that time screw plugs have been used elsewhere for the same purpose, placed in a similar way.

There are two rising mains from Brilliant Pumping Station to Highland Reservoir No. 1. The first one, of wrought iron, was laid in 1879 and coated with cold asphaltum paint. The second line is a 50-in. steel, laid in 1891, and coated with mineral rubber dip. The first line was entered some four years ago, and, while the rivet heads were somewhat deeply scored, with considerable incrustation and heavy pitting, the line would not be considered to be in serious condition for its age.

A short time ago there was a break in a cast-iron line on the hillside, in the vicinity of these rising mains. For a short distance there was a large trench open for laying a new steel main. The rush of water gushed out of the broken line, undermining and exposing the others. The settlement under the steel main was sufficient to cause it to be ruptured in two places and we were thus able to make an inspection of the interior of this line at that time. There was much scoring of the rivet heads; also, tubercles the size of a walnut, with pits underneath. Later, upon exposure to the atmosphere and elements, these tubercles dissolved and the rust seemed to extend and travel underneath the coating between the pits. Upon original inspection, while the pipe was wet inside, the coating seemed to be in good condition, as well as the steel plate underneath, and apparently would have remained so if it had not been for the drying out, due to exposure.

Some experiments, made in 1905, determined the value of "n" in the Kutter formula, for 3.8 feet velocity, as .022 for the twenty-one-year-old, painted wrought-iron pipe; and .017 to .019 for the eleven-year-old hot-dipped steel pipe which had been cleaned once.

The exteriors did not lend themselves so well to comparison, because about the wrought-iron line there was a protecting layer of sawdust and crude oil, about 2 in. thick, and the line was very thoroughly cared for by this method. The steel line was not in as good condition, and had a number of places abraded; the exposed areas have since been recoated. Some of the deterioration of coating on the outside may have been due to the scour of the sand and water.

It is interesting to note that at the places where the steel main broke, due to the weight of the undermined section, there was not a single place where the plate had been torn, and in every place rivets were sheared. It is interesting to see how the rivets, which were of wrought iron, first started to tear at the heads and were then cut off completely at the face of the plate.

There was a 50-in. steel line about 5 miles long, laid in Pittsburg in 1905–6, which was also coated with mineral rubber dip, through the city's streets, but which is of too recent history to afford much comparison. Except for a small portion of the end of this line, about 30 in. in diameter, no opportunity has been had to see the interior, but in this place it was in excellent condition. Wherever exposed it has been found to be in good condition, except at one spot on the South Side, on the 30-in. line above mentioned, where electrolysis had done considerable damage before it was found out.

Pittsburg has suffered from electrolysis, as most other cities having a traction system have. The remedy has been to bond lines by copper cables running from proper points back to the bus bars at the power station, and this has been quite successful. The steel line offers a ready means for transportation of the electric current, when it is once in the metal, because there are no lead joints, except at some valves, and these have copper bonds around these joints. The method used is apparently paying for itself and is very successful, not only in steel line, but for the cast iron, where there is no bonding around the joints.

MR. R. S. WESTON.* I had hoped that some of the engineers from Pittsburg would describe the process of making the iron or steel used in the manufacture of riveted pipe, for I think the

* Sanitary Expert, Boston, Mass.

members would have been as much interested as I was when a prominent metallurgist took me through a large steel works the other day. The process of making open-hearth steel consists in heating the pig iron, which contains much carbon, silicon, phosphorus, and sulphur, in the presence of oxygen in such a way that the impurities are burned out by the oxygen or absorbed by the basic or acid clay lining of the furnace. To furnish additional oxygen and to increase the fluidity of the molten metal, iron oxide, ferro-manganese, and other materials are added in the form of lumps which are thrown into the furnace by hand. The furnaces for making open-hearth steel consist practically of a shallow tank with a refractory lining. Over this shallow tank or hearth a gas flame plays while the metal melts into a seething mass. The sulphur and carbon are burned out and the phosphorus becomes burned out or absorbed by the lining. At the end of the process which, as Mr. Kuichling has said, is determined largely by the experience of the iron master, the molten metal is run into large ingot molds. These may be as large as 20 in. square and 6 or 8 ft. high. These ingots cool or freeze exactly as do blocks of artificial ice. The pure steel cools first and is on the outside of the ingot, while the center, especially near the top and bottom, contains the highest percentage of impurities. When the ingot is rolled or hammered the impurities exist as streaks in the finished product. These streaks of impurities may consist of manganese sulphide, a compound of manganese and sulphur. This fact is not surprising when it is remembered that the manganese in the form of lumps of ferro-manganese as large as one's fist is thrown into the furnace by the shovelful and its mixing with the molten metal is dependent very largely upon the chemical reactions within the furnace and that agitation which occurs when the metal is run into the ladle and from thence into the molds. There is always the danger that the product will not be homogeneous. When the ingot which has its impurities more or less localized is rolled out into a sheet, the latter will also contain localized impurities. The impurities have a different electrical potential from the pure steel; electrolysis is set up in the presence of water, and wherever conditions exist in any part of the metal where electrolysis takes place, that part will corrode a great deal more quickly than where the metal is

homogeneous. Thus pitting occurs in spots adjacent to small particles of impurities. Wrought iron is much less readily attacked because it is usually more homogeneous. There is no reason, however, why steel cannot be made as homogeneous as wrought iron if sufficient pains be taken with it.

The *Engineering News* * about a year ago published a very interesting article by Prof. Henry Fay, of Boston, on the failure of steel rails due to the presence of manganese sulphide. It was found that the manganese sulphide would segregate in spots in the rail and would form a center for corrosion or deterioration. It was often the case that the rail would crack, and at the point of fracture manganese sulphide was found in almost every case. Other investigators have shown that steel cannon have failed for the same reason. This experience has led to the production of ingot iron, as several speakers have mentioned. This latter contains little manganese, and more care is taken to have the metal homogeneous. The manufacture of steel plate from this ingot iron seems to offer the greatest hopes for the production of a metal highly resistant to corrosion.

Regarding coatings, the speaker would say that it has always seemed to him that the first requisite of a coating is to keep the water away from the pipe, and the reason why some of the varnish coatings like the Sabin coating succeed better than some others is because it is baked on the surface of the hot metal. This process tends to drive the water away from the metal and to allow the coating, so to speak, to get next to it. Mr. Kuichling's remarks that the definition of asphalt is in a muddy condition is explainable to some degree by the fact that it is the "mud" in the asphalt which makes it hard to define. Trinidad asphalt may contain 25 per cent. of matter besides what chemists call, in a very indefinite way, bitumen. This 25 per cent. of material is more or less soluble in water, consequently if one puts Trinidad asphalt or any partially soluble asphalt upon a pipe or upon iron or steel, the soluble matter will dissolve out, leaving a porous coating, the water will come in contact with the iron, and because iron is soluble in water, and especially so in water which contains neutral salts or acid salts, the metal will corrode, the more readily

* *Engineering News*, Vol. LXIII, p. 381.

the more streaky is its structure. On the other hand, if certain mineral waxes and coal-tar pitch preparations were used, better results would be obtained. Pure bitumen is practically insoluble. It has been found between bricks exposed by the excavations at Nineveh. It is difficult to apply any coating to a metal in a continuous sheet and to get it on to the iron without a layer of moisture beneath; thus many coatings fail because of imperfect application.

MR. MORRIS KNOWLES (*by letter*). The steel and wrought-iron mains referred to have taper joints, with smallest diameter 50 in.; thickness of plate for steel main, $\frac{3}{4}$ in. for 1 800 ft. and $\frac{5}{8}$ in. for 2 000 ft. There were no records of the thickness of the wrought-iron pipe, and present calipering would be subject to too much error.

The steel main was cleaned in 1896 by scrapers and wire brushes and then repainted.

MR. E. KUICHLING (*by letter*). The discussion of the paper has brought out a number of highly interesting experiences and opinions. Mr. Luce's notion that wrought iron is more porous than mild steel, and that preservative coatings of paint, varnish, or enamel adhere more tightly to surfaces of wrought iron than to steel, because some of the coating material flows into open pores, implies that the pores are of such shape as to lock the covering substance mechanically to the metal by a vast number of extremely minute bulbous stems or dovetails. A porous structure of this kind was not revealed by the microscope in many examinations of iron by the author, except after the action of strong acid, and then only in comparatively few places. It is possible, however, that the manner of preparing and viewing the samples was at fault.

The statement is also often heard that the surface of rolled wrought-iron plate is much rougher than that of steel plate. This may be due to differences in the finish of the rolls, as there seems to be no good reason for the same rolls producing a rough or porous surface on one metal and a smooth or dense surface on the other. The chances for variation in the composition of the coating material, and its mode of application, are far greater than any possible difference in character of surface. Roughness of metal surface implies that the coating is uneven in thickness, and hence

of unequal strength and intensity of adhesion, whereas the opposite results are claimed. The subject requires much closer study before a satisfactory explanation can be given.

In considering the life of relatively thin pipes of iron and steel, the original thickness of the metal seems to be a very important factor. The steel plate of the 60-in. Allegheny main, cited by Mr. Knowles, is 0.5 in. thick, and the thickness of the two Pittsburg rising mains are said to be considerably greater. It is needless to say that under like conditions of corrosion a thick plate will last longer than a thin one.

The computed values of the Kutter coefficient "n" given by Mr. Knowles for the Pittsburg riveted mains are very interesting, but they should be supplemented by stating pipe diameters and plate thicknesses, as well as time and manner of cleaning the steel main. In a description of the Pittsburg water works published a number of years ago, it was stated that the old wrought-iron pipe was 48 in. in diameter and 0.75 in. thick. This plate thickness seems excessive, but if correct it will account for the high value of "n," owing to the relatively large difference in diameter at the circular joints.

The remarks of Mr. Weston furnish excellent reasons for the pittings so often found in steel pipes, and also for the occasional failures of bituminous coatings. They indicate that there is room for improvement, not only in the fabrication of steel, but also in the composition and application of preservative coatings, and it is to be hoped that he will point out in other papers how advances in these directions can be attained.

THE CORROSIVE ACTION OF WATER ON METALS.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON.

[*Read September 23, 1910.*]

It is not intended that this paper be a theoretical treatise on the nature of water and its solvent action on metals, for that side of the question has been discussed ably by Whitney (1),* Cushman (2), Walker (3), Kanolt (4), and others, and in the JOURNAL of the New England Water Works Association by Mr. Harry W. Clark (5), who has described the investigations which he made, under the direction of the Massachusetts State Board of Health, into the action of water on lead service pipes; also by Mr. Freeland Howe, Jr. (6), whose paper treats of the general subject. Furthermore, it is not the plan to list all the troubles which are familiar to most water-works managers, but rather to outline a few of the causes, effects, and remedies, with the hope that those who meet with the same in practice may be moved to contribute from their experience to the discussion.

WHY DOES WATER CORRODE OR DISSOLVE METALS?

There is no metal which is absolutely insoluble even in pure water. There is little pure water obtainable, and the greater the amounts of certain impurities in the water, the greater the solvent action it has for metals. Iron is quite soluble, zinc more so. This tendency of a metal to go into solution is called the "solution pressure"; that is, the molecules of the metal tend to diffuse among the molecules of the water just as a little sugar, even if not stirred, tends to diffuse in a cup of hot water and to sweeten the whole cupful. The amount of any metal which will dissolve in absolutely pure water is very limited, and the action soon comes to a standstill. The theory of this action has been explained by physical chemists and is known to most of you as the "*electrolytic theory of corrosion.*" This theory states that water is partly dissociated into its hydrogen (H) ion and its hydroxyl (OH) ion.

* Numbers refer to the references at the end of the paper.

"*Ion*" is a synonym for "*component.*" When a metal is immersed in water a "*battery*" or electrolytic effect is produced, and a certain amount of the metal is replaced by the hydrogen component of the water. The hydrogen goes into gaseous form and the metal into solution. In pure water this action soon comes to a standstill, because a film of hydrogen gas collects on the surface of the metal and, being a non-conductor, really shuts off the current, that is, polarizes the iron. Whenever anything like an acid — which increases the hydrogen side of the equation — or oxygen — which "*depolarizes*" the iron — is present, the action is accelerated; and when any substance containing hydroxyl, like lime or caustic soda, is present, the action is hindered or retarded. For example, iron dipped in weak acid dissolves rapidly, while the same dipped in lime water remains bright indefinitely. The most common acid in water, and the one most important, is carbonic acid (H_2CO_3), which dissociates into H and HCO_3. Thus, when large quantities of carbonic acid are present, the number of hydrogen (H) ions is greatly increased, and the well-known corrosive action of such waters is evidenced.

When oxygen is dissolved in water an oxidizable metal like iron corrodes more rapidly because the oxygen depolarizes the iron upon which the hydrogen tends to precipitate. It also rusts and throws the metal out of solution as fast as it dissolves; insoluble iron precipitates and leaves room for still more of the metal to go into solution. This oxidizes in turn and precipitates, and as fast as the iron oxidizes, the hydrogen, because of the so-called depolarizing action, is pushed off the surface of the metal in the form of bubbles, thus preventing the formation of a film of gas thick enough to protect the metal against solution. Waters frequently contain more than 14 parts of oxygen per million. The amount dissolved is dependent upon the temperature and pressure. Deep well waters are naturally quite free from oxygen, while surface waters are nearly always saturated, and those which contain very active growths of algæ are frequently supersaturated. On the other hand, ground waters, especially those from shallow wells, frequently contain considerable oxygen, probably because they are supplied in part by surface water. Therefore one may expect to find iron rust in most waters which attack iron. Some deep well tubes,

however, are corroded and waste away without the slightest trace of rust.

The kind of metal present also affects the degree of action of the water. All metals vary in their degree of solubility. Sodium, potassium, and calcium dissolve very rapidly and with the evolution of considerable heat; while gold and platinum are practically insoluble even when certain strong acids are present. Between these extremes lie the different metals used in water-works practice. The following table of metals, arranged in the order of their solubilities, is of interest.

Aluminum.
Zinc.
Iron.
Nickel.
Lead.
Tin.
Copper.

The order given in this table has been determined by measuring what is called the "*solution pressures*" of the various metals. These results give them their relative positions in what is known as "*the potential series of the metals.*" The fact that water acted on metals in the order given in the table was known by practical men long before it was confirmed by the experiments establishing the theory.

Electrolysis is another factor which influences corrosion. If iron and zinc are placed side by side in water which attacks them but slightly, and connected with one another, the zinc will go into solution and the iron remain. This principle is made use of in copper mines where the waste waters, containing valuable copper, are passed over iron chips, when the iron goes into solution and the copper takes its place. In similar cases the least soluble metal will remain unaffected.

It is a well-known fact that no iron dissolves from galvanized iron pipe until the zinc near the point of corrosion has disappeared. Lead-lined and tin-lined iron pipe frequently fail because the iron has an increased tendency to go into solution in the presence of lead or tin. Tin-lined iron pipe is more subject to corrosion. It is a fact that tin shrinks after it crystallizes, leaving numerous

cracks through which the water can pass to the iron pipe through the tin lining. It has generally been believed that a tin lining will protect lead pipe against solution, but experiments, with the assistance of Miss H. R. Hosmer, with lead pipe lined with pure tin and exposed to the action of distilled water, natural surface water, and natural ground water, showed the presence of varying amounts of lead in all of the sixteen samples held in contact with the tin lining, and — what was surprising — the absence of tin from every one. The amounts of lead dissolved from tin-lined pipe in the above-mentioned experiments are given beyond. In these experiments the sample of ground water and one of the three samples of surface water were kept in the laboratory for several weeks. They lost carbonic acid while standing, and their diminished corrosive action due to this loss may be noted in the following table of results, experiments numbered 1 to 14.

SOLUBILITY OF LEAD FROM TIN-LINED LEAD PIPE.

Experiment Number.	Kind of Water.	Period of Contact.	PARTS PER MILLION.	
			Lead.	Tin.
1	Ground.	1 day.	4.60	0.0
2	Filtered surface.	1 „	10.10	0.0
3	Ground.	5 days.	1.10	0.0
4	Filtered surface.	5 „	5.10	0.0
5	Ground.	18 „	2.80	0.0
6	Filtered surface.	18 „	4.00	0.0
7	Ground.	14 „	3.80	0.0
8	Filtered surface.	14 „	3.80	0.0
9	Ground.	19 „	2.20	0.0
10	Filtered surface.	19 „	2.20	0.0
11	Ground.	43 „	0.70	0.0
12	Filtered surface.	43 „	1.00	0.0
13	Ground.	21 „	1.50	0.0
14	Filtered surface.	21 „	4.00	0.0
15	Unfiltered surface.	15 „	2.20	0.0
16	Unfiltered surface.	15 „	3.50	0.0

No tin was dissolved in the presence of lead. The two metals have a different solution pressure and the lead will dissolve as long as any tin is present. This was confirmed by another experiment where pieces of pure tin and pure lead were connected with a wire and suspended in water.

The stray electric currents from street railways, lighting and telephone systems, when pipes are laid in damp soil or are exposed to water, will carry metals with them just as metals are carried from one pole to another in an electric plating bath. The action is exactly analogous to the action described above, where the two metals connected with one another were immersed in water. Solution generates electric current, and electric current can cause solution. It may be said that the essential factors for the solution of any metal in water are an electric current and the presence of a less soluble substance of a different electrical potential. For example, if a piece of iron in water be connected with a piece of scale which has a different potential, an electrical current will result and the iron will be dissolved rapidly. As is well known, wrought-iron services are very long-, and steel services very short-lived. The former are made of nearly pure iron; the latter contain more scale, more particles of manganese sulphide, more sand grains and other impurities tending to establish electrical currents when the metal is exposed to water, thereby increasing the speed of solution or corrosion. The fact that the wrought-iron grillwork on old buildings lasts so much longer when exposed to the elements than the modern steelwork is an evidence of this fact.

Whipple (7) (Eng. Rec., *62*, 118) investigated the cause of the "red water plague" at Springfield, Mass., and found that it was not due appreciably to the introduction of a new filtered water supply, as had been feared, but rather to the use of unprotected steel tanks and of low-grade galvanized steel pipes for the hot-water supply systems where most of the trouble occurred. This action was far more apparent than any action due to the removal by the filter of organic matter, which in many water supply systems forms a protective coating on the insides of pipes and tanks and aids in the resistence of corrosion, but which when removed exposes the pipes to the action of the water.

The waters most apt to cause electrolysis are those which contain large amounts of dissolved mineral salts, such as chlorides, carbonates, and sulphates. These increase the conductivity of the water, and hence the corrosion due to electric currents. Mr. W. F. Monfort (8) has shown that the corrosion of pipes, meters, and

valves of the St. Louis supply, after treatment with lime and ferrous sulphates, was due chiefly to this electrolysis. His investigations showed that the zinc coatings on galvinized iron pipes and gratings disappeared rapidly, and that in meters where bronzes of three different compositions were used, those containing the highest proportion of the more readily soluble zinc and aluminum corroded most rapidly. These facts were especially interesting because the water did not attack iron, although it was alkaline and contained neutral carbonates and at times free lime (therefore, hydroxyl). There is no *red-water plague* in St. Louis, although the water does attack appreciably the somewhat soluble aluminum. Naturally, Mr. Monfort recommends that homogeneous materials be placed in contact with this water and that one kind of bronze be used for meters and valves. Tinning bronze did not protect against corrosion any more than it protects lead or iron pipes.

Another source of acid and corrosion in water is the humus matters in peaty waters. The water of Dismal Swamp of Virginia, for example, attacks iron rapidly. But, as Mr. George W. Fuller (9) states in a recent paper, "It does not seem to be perfectly plain, however, how far the acid character of peaty waters may be due to carbonic acid and how far to complex and obscure organic compounds"; yet such waters, especially the moorland water in parts of England, have so marked an action on lead pipe as to make it necessary to treat them with lime or soda in order to neutralize the effect.

Mr. J. W. Ledoux (10) has shown that the swampy water which supplies Charleston is highly corrosive before filtration. With the removal of most of the organic matter by treatment with sulphate of alumina and filtration, the corrosive effect is reduced to a minimum. The treatment, however, cannot be carried to such a point that all of the color is removed. To do this it is necessary to add so much sulphate of alumina that there is an excess, and corrosion due to this excess is produced. Corrosion due to this cause can be corrected by the addition of lime; but if this be done the removal of color is not satisfactory. Mr. Ledoux does not state whether or not he has tried the effect of adding lime after the color has been removed by filtration with the aid of a sufficient amount of sulphate of alumina. Experiments in England by C. C.

Smith (11) would indicate that such a practice would be successful.

The waters most liable to attack metals are pure waters containing large amounts of carbonic acid and oxygen. Waters which contain, like the St. Louis water, high amounts of dissolved neutral salts are most liable to set up electrolytic action when two different metals are exposed to them.

PROTECTIVE COATINGS.

The action of the water is retarded by coatings which form on the insides of metal pipes, the simplest and most common of which is iron rust. This forms frequently a so-called tubercle, beneath which the iron is often bright and rust-free. In this case there is sometimes an accumulation of gas — perhaps hydrogen — which prevents the further action of the water. When ground waters act on lead pipe, a basic carbonate of lead collects on the inside. This retards the action, just as does the iron rust, and it is a matter of common knowledge that such waters attack new lead more rapidly than old, that is, those on which the coating has formed. Again, the suspended silt in some western river waters acts in a similar manner. There are in existence iron water-works intakes in these streams which have been in use for over fifty years and which show no appreciable corrosion.

The organic matter in many New England surface waters effectually protects against corrosion. The writer has had the lead service pipes of Concord, Mass., under observation for ten years, and observed no more corrosion in the year 1910 than in the year 1900. Frequently this organic matter is removed by filtration, and after a few years complaints begin to appear, due not so much to the slight percentage of increase in the amounts of carbonic acid or conductivity (due to the addition of sulphate of alumina) as to the disappearance of the gelatinous organic coatings from the insides of the pipes. At Exeter, N. H., which has been supplied for four years with filtered water, always alkaline and free from sulphate of alumina, there have been some complaints recently because of "*red water*" in the hot-water systems. This may be due in part, as at Springfield, to the poor quality of the pipes and tanks, but the writer believes in great part to the removal of the

organic matter by filtration. The effect of filtering such water is like changing from a colored surface to a clear ground-water supply. This change has been known to increase corrosion. Slow sand filters might effect an equal or greater increase in the amount of carbonic acid, but because the removal of organic matter would not be so complete, it is probable that there would be more protection afforded by the organic matter collecting on the insides of the pipes. In the writer's opinion most of the increased corrosion of pipes ascribed to filtered water is due to the withdrawal of organic matter which would form a protective coating.

Monfort (8) has shown that calcium and magnesium carbonates collect on the insides of the service pipes at St. Louis and protect them against corrosion. Similar observations have been made where water softened with lime and soda has been distributed.

The lining of iron pipes with tin is some protection, but unless the fine cracks become filled, the iron will corrode. Lead is not so apt to dissolve from lead-lined iron pipe as from pipe made of pure lead; the presence of iron helps to prevent this action, the iron being the more soluble metal.

Certain silicates in water form protective coatings, and the best artificial lining for service pipe is the silicate of calcium which one one calls "hydraulic cement." Pipes lined with cement have been in use for many years, and recently one city has been advised to line a riveted steel pipe with this material. While cement lining has the disadvantage of being brittle, it is an effective protection against corrosion, both because of its alkalinity and its impervious nature. It should be recommended for services where water attacks lead or iron pipes and where wooden pipes are impracticable. The idea would be an elastic alkaline coating, say a bituminous Portland cement.

HOW CAN CORROSION BE AVOIDED?

While the causes of corrosion, though far better understood now than formerly, may be obscure, the remedies are obvious and not difficult. An excess of carbonic acid in water may be removed by aëration or by the addition of sufficient lime to combine with it. Aëration generally suffices. As an increase in the hydrogen ions increases the corrosive power, so an increase in the opposite hydroxyl

ions decreases it. The addition of enough alkali — that is, hydroxyl ions — to make a water neutral to phenolphtalein (an aniline dye used to test for alkali) is generally sufficient to overcome this corrosive action. While this practice is not usual in this country, it is common enough in England to warrant its adoption wherever necessary. If a water contain dissolved salts, even though alkaline, homogeneous metals should be used in contact with it. The insides of meters, valves, and pipes, wherever possible, should be of such a composition that electric currents will not be generated. Cheap steel pipe containing scale and other impurities should be replaced with high-grade metal, and where necessary, wood and cement-lined pipes should be used. No one should attempt to fasten a copper screen with galvanized iron staples unless it is desired to have the staples disappear. If, on the other hand, a galvanized iron screen be fastened with copper staples, the screen will go first.

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DISCUSSION.

HAROLD C. STEVENS, ESQ.* The Board of Water Supply of the city of New York, in connection with the design of sanitary works for the protection of watersheds through which the Catskill aqueduct is being constructed, has had occasion to seek information regarding the effect of hypochlorite of lime solution upon metals, and in the operation of the works has gained further information. Systematic observations have not been made, and the corrosive effects under apparently similar conditions have differed quite widely; but the data obtained indicate in a general way what to expect.

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Wrought-iron pipe is most readily affected. The inverts of 2-inch pipes having a trickling flow of a one per cent. solution through them have been completely rusted through in about four months. Three-inch galvanized iron pipes, conveying at different times one per cent. and one-half per cent. solutions and flowing full, were replaced after about a year's service, not on account of rusting through, but on account of clogging due to the formation of tubercles and the accumulation of a deposit of lime. These pipes probably lasted longer than would have been the case with the plain wrought-iron pipes, because zinc is quite resistant to corrosion, and, where galvanizing is perfect, would prevent the formation of tubercles long enough to permit the coating of lime to form and prevent further corrosion. The galvanizing of commercial pipe is far from perfect, however, and also in making joints the zinc coating is necessarily injured, so that only a partial protection of the iron results. Galvanized stove-pipe has remained in serviceable condition for four months, while plain iron stove-pipe in the same place has been ruined. The galvanizing, however, now shows rust specks all over.

Brass pipe is corroded by hypochlorite of lime solution, but very much less than iron; in fact, very slowly. Tubercles do not form and the pipe becomes coated with a smooth layer of lime that protects the brass from further action. The effect on the flow in this case is due only to the gradual reduction in the size of the duct. It seems reasonable to expect that brass pipe, say 2 in. in diameter, would last two or three times as long as iron pipe, before renewal or cleaning would become necessary. Moreover, the coating in brass pipes could be cleaned out with acid and the pipe be made as serviceable as originally, with threads uninjured, whereas iron pipe so cleaned would be found rough and a great deal damaged.

At Board of Water Supply plants, where a two per cent. solution was used for one month and a one per cent. solution thereafter, bronze float valves are practically perfect after four months' service with a trickle of solution flowing through them, but the seats have become coated with lime and consequently do not close properly. On scraping off some of this coating the bronze appears to be intact. A long brass valve stem in a hypochlorite of lime

solution tank after three months showed general pitting, but to a very slight depth. A brass screen of about No. 18 wire immersed in the solution was destroyed in less than four months, while another, under almost like conditions, has remained in good condition. The screen destroyed was made of very soft brass.

From such observations as were available at the time of designing certain of the Board of Water Supply plants, it was thought that copper of about 20 gage would be a good material for orifice cans, floats, and for lining small tanks. Its value was much overestimated, however, for in one case a copper tank lining was eaten through in less than three weeks; and in another case an orifice can become leaky in about three months. Floats made of No. 22 copper have become leaky in about three months, being badly pitted on all the surface in contact with the hypochlorite of lime solution. The leaky orifice can was effectively repaired with solder which has resisted corrosion very well. It has not been pitted and the only effect upon it that has been noted has been a blackening of the surface.

Tin appears to resist the action of hypochlorite of lime solution very well. Two ordinary tinned copper ball floats, in solutions of one-half per cent. to one per cent. strength, lasted for nineteen months, and one was still serviceable. A similar larger float, in 2 per cent. solution for one month and in 1 per cent. solution thereafter, has been in service for four months and appears to be in perfect condition. There is a slight coating on the surface, but if this is scraped off, bright tin appears underneath.

Bronze orifice plates made of "Worthington anti-corrosive metal" have stood well. The edges are not quite so sharp as originally, but the discharge coefficient has increased during nearly two years of service only about three per cent. Part of this effect can be attributed to wear rather than corrosion.

The effect of hypochlorite on one large metal supply main was to detach the organic matter, which quickly appeared at the reservoirs. The next gaging of the pipe showed an increase in carrying capacity of about six per cent. from the previous year, whereas theretofore there had been an average yearly reduction of about four per cent. in carrying capacity. It is to be expected that similar effects would always be observed in supply mains leading

from reservoirs, for in such cases vegetable growths have a large effect on the carrying capacity. No observations have been made on the corrosive effects in metal mains, but a strong hope seems justified that no material damage will result, since the dose is minute and by far the greater part of the applied chemical is taken up by organic matter in the water before it has a chance to come in contact with the pipe. The point of application of the chemical would, of course, have an effect on the results. A relatively long period between the application of the dose and the entrance of the treated water into the pipe would lessen the tendency to action on the pipe.

Wood is readily affected by hypochlorite solution. Mixing tanks of white pine began to show serious damage within a month, the end grain at the rabbet being affected most and so softened that it could be crushed or scraped out. Storage tanks containing two per cent. solution were not much affected during the same time. All tanks, however, were lined with cement mortar shortly afterwards. Wooden stilling boxes have lasted for nearly two years in solutions of one-half per cent. and one per cent. strength, but at the end of a year and a half the wood was found to be so softened that the edges could be broken off with the hand. Wooden floats boiled in paraffine and coated with a thick layer of paraffine have been used successfully. They appeared to be entirely unaffected after many months of service.

Mr. Edward D. Eldredge.* We have had rather an interesting example of corrosion occur lately in the internal parts of a pump close to the composition valve seat. The cast iron was originally fully an inch thick, but a hole appeared entirely through the iron. The hole was chipped out round, tapped, and a $\frac{3}{4}$-in. pipe plug put in. Not many days after, the plug became loose, the iron being further corroded, the hole was tapped larger, and an inch plug put in. The hole for the inch plug gave an opportunity to reach down with the finger to the under side of the plate, and there were cavities there which indicated that at some parts the iron was not over a quarter of an inch thick. This was in the cylinder of the pump, a part of the main casting, and it made it necessary to condemn the cylinder. I should like to hear any

* Superintendent Onset Water Company, Onset, Mass.

discussion on the subject as to what was the cause of such a corrosion, my idea being, not that it was electrolysis from any stray current, as such conditions did not exist, but that it was due to the presence of an excess of composition — the subject which Mr. Weston referred to; that the excess of composition in proportion to the amount of iron set up an action there which corroded the iron. The piston, piston rod, cylinder lining, valve seats, etc., were of brass. The case seemed to me to be more marked than any other I had ever known. The new pump will have a cast-iron piston and steel rod. I shall expect any corrosion that may occur to show itself on the iron piston, which can easily be renewed if necessary.

MR. SAMUEL A. AGNEW.* I do not intend to go into the scientific reasons for this, but I am rather surprised at some of the things Mr. Weston has told us, and I guess there are a number of others who feel the same way. For instance, referring to galvanized iron pipe, I always supposed that we used galvanized iron pipe because the galvanizing was not dissolved in the water the same as the iron was. As I understand from Mr. Weston, it is actually dissolved, but so long as there is any galvanizing there it so saturates the water that the water does not affect the iron. Did I understand this correctly?

MR. WESTON. Locally, yes.

MR. AGNEW. This is rather a surprise to me, because I have often found the pipe eaten into where the galvanizing has been broken off at the ends to the extent that the pipe has started leaking. Now, according to this theory, so long as the galvanizing is there to keep the water saturated with this material, there is no room left for the iron to penetrate the water. I should like to have an explanation so I could understand it a little better.

MR. WESTON. The explanation of that point is rather complicated, as there are two actions going on. First, there is the solution of the zinc in the presence of iron; and then there is the protection of the zinc coating itself, the zinc rust combined with the organic matter. Probably in a great many waters the latter is a much better protection to the zinc than any iron-rust coating is to the iron. After the galvanized coating disappears, the iron

* Superintendent Scituate Water Works, North Scituate, Mass.

beneath the galvanized iron coating goes very much more rapidly than the zinc went, because the iron rust formed does not protect the iron to the degree that the zinc rust protected the zinc. One must not confuse the protective coating idea and the solution idea. Those two things are entirely distinct and they complicate each other. Mr. Eldredge's question I can only answer by mentioning cases where ordinary cast iron, the material composing the pump chamber Mr. Eldredge spoke of, exposed to water containing silica, had become so soft that it could be cut with a knife, most of the iron having changed over from metallic iron to iron silicide. In this case the silica in the water had interchanged with the iron, the iron going into solution and the silica combining with the remaining iron making a soft iron-silicate. There are other similar cases on record. Such cases occur generally in ground or sea water containing a good deal of silica.

One additional word with regard to the organic matter which affects pipe. Organic matter in a great many waters is not in solution, but in a state of finely divided suspension. It is in gelatinous form. When an electric current is passed through water containing this gelatinous matter the latter migrates to the iron, and plates out on its surface just as silver plates on copper in an electric plating bath; this peculiar gelatinous substance is a great protection to all metals exposed to water. On the other hand, if there is present humus matter, or organic matter such as we find in the Dismal Swamp water, that is of an acid character, it acts like the chlorine in bleaching powder or like carbonic acid, interchanging with the iron, and the iron thus freed goes into solution. Thus when we say organic matter, we mean two things, — acid organic matter which corrodes, and gelatinous organic matter which protects.

THE PRESIDENT. I would like to ask Mr. Eldredge if his supply is from wells.

MR. ELDREDGE. No, it is from a pond which is fed entirely from the bottom, there being no surface inlet or outlet. It is practically natural filtered ground water that has been exposed to the air.

MR. W. C. HAWLEY.* Referring to the matter of the deteri-

* Engineer and Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

oration of cast-iron pipe, the original 12-in. main in Atlantic City was laid in 1882. In fifteen or twenty years the character of the metal had changed to such an extent that with a jack-knife you could readily cut into it from one eighth to one quarter of an inch in depth. Before the steel main was laid, in 1901, we took out some sections of the old 12-in. pipe where the action had apparently gone entirely through the shell of pipe.

We have had rather an interesting experience with hypochlorite of lime. We began using it some six or eight months ago, before we completed our filter plant. The galvanized iron pipe through which the solution is fed to the suction well is still in very good condition except where cutting threads on the pipe removed the galvanizing. Ordinary brass is quickly attacked, but a good grade of bronze shows no sign of damage. About the time we began using the lime, we were forced, on account of repairs to the other engine, to run one of our large engines for some months without being able to get into the condenser, which is located on the suction pipe, to examine it or clean it. Our vacuum began to reduce and dropped off from about twenty-six inches to about nineteen inches, but within twenty-four hours after we introduced the hypochlorite the vacuum had increased to about normal. I began to be frightened for fear the hypochlorite might injure the tubes in the condenser, and we shut down long enough to examine them, but found that no damage had been done to the tubes but that they had been thoroughly cleaned of all organic matter and sediment which had collected on them and they were left clean and in good condition.

MR. WILLIAM F. SULLIVAN.* The difference in the ruling prices between plain wrought-iron pipe and galvanized iron pipe is about ten per cent. I would like to ask Mr. Weston if his researches would indicate that that difference in price would be offset by the life of the galvanized pipe.

MR. WESTON. It is difficult to answer Mr. Sullivan's question directly because some waters form a protective coating on the surface of the zinc and others do not. In the case of a water containing little mineral matter and much carbonic acid, for example, a pure ground water, a protective coating would be very slight,

* Engineer and Superintendent, Pennichuck Water Works, Nashua, N. H.

the zinc would dissolve rapidly, and galvanized pipe would not pay. On the other hand, most New England surface waters attack zinc very slowly and form good protective coatings. The additional benefit which would accrue from having pipe which does not clog with iron rust is worth the extra price of galvanizing when this kind of water is passed through it. In other words, the character of the water must be taken into consideration; if it attacks zinc rapidly it hardly pays to use galvanized iron pipe with it. If it is like most New England surface waters, like the water of Mr. Sullivan's city, Nashua, for example, it does decidedly pay, because the zinc rust is white, the iron rust is red, and one does not notice the zinc rust in water.

I fear that I did not answer Mr. Agnew clearly enough. The electrolytic action between iron and zinc and galvanized iron pipe is very much localized. If the zinc had dissolved or had worn off one end of the pipe and the iron was exposed, and if the zinc coating some distance from this point was attacked, it would not protect the exposed iron some distance from it. The resistance of the water to the passage of electric currents between distant points is so great that the electrolytic action is usually local. If an ordinary galvanized iron nail be put into pure water stiffened with agar, a jellylike substance, solution of the zinc begins immediately, but only at certain points. The whole length of the nail may be a series of alternate positive and negative points, the solution taking place at the negative points only. Sometimes there are four or five positive points and four or five negative points along the length of a nail three inches long. One would expect to find the same phenomena inside a service pipe, namely, alternate negative or solution points and non-solution or positive points.

MR. KUICHLING. Do they not also interchange and keep changing? What are negative to-day may be positive next week?

MR. WESTON. Yes.

MR. KUICHLING. And for that we have no good explanation?

MR. WESTON. No, sir.

ICE FORMATION.

BY H. T. BARNES, D.SC., MACDONALD PROFESSOR OF PHYSICS AND DIRECTOR OF THE PHYSICAL LABORATORIES, MC GILL UNIVERSITY, MONTREAL.

[*Read September 22, 1910.*]

I have the honor to present in this paper a brief account of the main results of a study for many years of the ice conditions on the St. Lawrence River. I have no doubt many, if not all, the members of the Association have had practical experience of the formation of ice in connection with water works, and I should deem it a great privilege to have discussions from those who have to deal with practical problems.

Being ice bound for so many months of the year, the St. Lawrence has offered favorable facilities for studying ice formation on a large scale. The river is not subject to floods, as are many of the American rivers; its flow is more uniform, but it experiences floods at many places for a short time each winter and spring, due to the accumulation of ice. A royal commission was appointed in 1885 to study the cause of the floods which produced so much inconvenience at Montreal. A very valuable and comprehensive report was issued giving an account of the general ice conditions of the river. A large number of maps were also produced, illustrating the exhaustive ice survey made at the time. The conclusions arrived at by the commission were that the floods were caused by the accumulation of frazil and anchor-ice and the general stoppage of the channel caused by the winter ice pack. They advocated keeping the river clear of ice from Lake St. Louis to tide water, in order to give a free runway for the ice. Much attention was directed to the character of frazil and anchor-ice, and many attempts were made to find some connection between the temperature of the water and the formation of these ice masses. Ordinary methods of measurement were found to yield conflicting results, but the most careful series always showed practically

no deviation of the temperature of the water from the freezing point. This has been the universal experience of all who have attempted to follow the course of water temperature during the winter months. In 1895 I made a serious attempt at the problem employing a very delicate thermometer,* and I succeeded in showing that the temperature was subject to minute variations of the order of a few thousandths of a degree. Thus the total variation of temperature in the water during the winter probably never exceeds one or two hundredths of a degree unless from exceptional circumstances. Yet within the limits of so small a fluctuation tremendous physical effects are produced. Nowhere can one find a more wonderful exhibition of the delicate poising of the forces of nature.

Recent observations made on the river from the decks of the Canadian government ice-breakers, which were kindly permitted by the Department of Marine and Fisheries, have confirmed the earlier conclusions.

In nature we find three kinds of ice formed, — surface ice, frazil-ice, and anchor-ice. The circumstances giving rise to the production of any of these forms are now well understood and easily recognized.

Without going too deeply into the theoretical reasons for many of my conclusions, I wish to point out as briefly as possible what I have found characteristic of each of these forms of ice.

SURFACE ICE.

In a lake or quiet river not flowing with sufficient rapidity to produce serious eddies, we find with the advent of cold weather and the approach of the water temperature to 32° Fahr. that there is a tendency to form ice. Depending to a large extent on the vagaries of climate or direction of wind, the ice forms first along the shores and gradually extends out on all sides. Several conditions must hold before the surface can be entirely covered. The water must be at or very near the freezing point, the air temperature must be at or below the freezing point, and the wind must be practically zero in order that no ripples be produced. The latter

* Fully described in "Ice Formation," New York, John Wiley & Sons.

condition does not occur very often, but when it does the surface becomes covered with ice. Wind then no longer disturbs the surface and the growth of the sheet proceeds at a uniform rate. As long, however, as there are ripples, the surface cannot freeze in a solid sheet. The crystals of ice which are formed with a wind are broken up and prevented from freezing together. Surface waves are exceedingly effective in retarding the ice sheet.

Atmospheric humidity determines very largely the growth of the first ice cover. A dry wind will produce rapid evaporation and a consequent rapid absorption of heat. In a cold atmosphere the air over the water is warmed and is in consequence capable of absorbing more moisture than it can hold when blown away to colder parts. Hence the characteristic steaming of open water or thin ice, which is observed when the atmosphere is in the neighborhood of 10° Fahr. It can be readily shown that air of 25 per cent. humidity will increase the rate of growth of an ice sheet as much as 50 per cent. up to a thickness of about an inch, after which the influence becomes proportionately less as the sheet thickens. A cold, dry north wind blowing over water has a large influence on the formation of ice.

The exact temperature of the water also plays an important part in the formation and growth of surface ice. With water exactly at 32° ice will thicken indefinitely as long as the air temperature is below the freezing point, the rate of growth becoming very small for great thicknesses. It seldom happens, however, that the water is exactly at 32° under an ice sheet; it is usually one or two hundredths of a degree above freezing, and the influence of this is to produce a limiting thickness to which the ice will grow; or, in other words, a balance is finally produced between the heat carried away by conduction through the ice and heat supplied by convective streams of water slightly warmer than 32°, which bathe the under surface of the ice sheet. If the water is higher in temperature, due to bottom streams being deflected upwards by shoals or to warm springs, then no surface ice can form at all. Thus we often observe "air holes" in lakes or rivers otherwise frozen over. Measurements of the temperature of the water in these air holes have shown a temperature higher than existed under the surface ice in the immediate neighborhood.

RATE OF GROWTH OF SURFACE ICE.

As soon as the first thin layer of ice has taken over the surface of still water, the growth proceeds at a perfectly regular rate which may be calculated. The position of the first crystals are along the surface of the water, but as soon as the formation proceeds as a result of conduction of heat through the ice, then the ice crystals are all orientated with their principal axes at right angles to the water surface. It has been indicated by previous experiment that an ice crystal conducts heat best in the direction of the principal axis, and the fact that all such crystals are turned so as to transmit the heat of the water most readily indicates that this is so. The difference between conduction ice and conglomerate ice — that is, ice formed by the freezing together of irregular masses — is very great when considered with reference to their power of disintegration. Salt-water ice is a notable example of this, and the masses of such ice not being regular in crystalline structure take a very long time to melt. It is only conduction ice that forms on a smooth lake or river, the conglomerate ice being produced along the shores and in the bays of rivers flowing too swiftly to freeze over entirely, by loose masses of floating ice being blown inshore by the wind and freezing together.

There has been very little if any scientific work done in studying the rate of growth of surface ice, and the data available are practically useless. The question in any particular case is complicated by variable meteorological conditions, and the opportunity to accurately study the natural rate of growth of ice is not often at hand. Some exceedingly valuable results were obtained by my assistant, Mr. King, last winter while at work on the government ice-breaker *Lady Grey*. A quiet bit of water next the ship in the Louise Basin at Quebec was studied during a period when the tide was not running rapidly. Ice commenced to form over this water, and for a considerable time Mr. King withdrew, at intervals, portions of the ice sheet for measurement. This was kept up until an adverse wind and change of tide swept the whole sheet away. Nevertheless the observations were made with great accuracy, and, what is most valuable, simultaneously with observations by the microthermometer of the temperature of the water, the humidity, and the air temperature. We have spent a great

deal of time analyzing these results, and while we feel that more extended observations are necessary to verify and support the various points raised, yet the matter is of so much interest and importance that it warrants more extended observations being made. It is not possible in this paper to give an adequate description of the mathematical analysis necessary to arrive at the various conclusions, but this will be set forth later in another place.

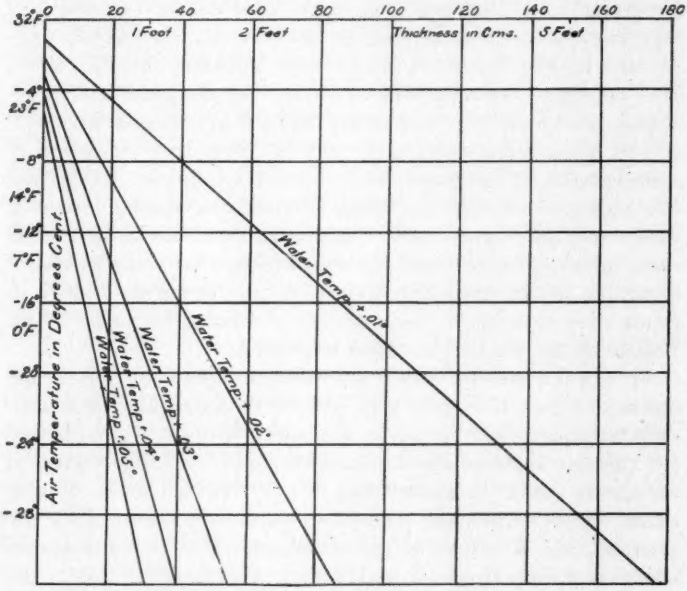

FIG. 1.

The main factor in surface ice formation is the conduction effect, but the rate of growth is affected by convection currents in the water, humidity of the air, which influences the evaporation, and the velocity of the air currents over the ice. Radiation is a small factor which comes into the calculations, both a gain of heat from the sky and loss of heat from the ice surface to the air. Accumulations of snow on the surface will produce an uncertain factor, but

nevertheless an important one which may be corrected for when the depth of snow is known.

Taking conduction alone, a theoretical expression of the type

$$\frac{K}{\rho L}\int_0 \theta dt = x\left(lo + \frac{x}{2}\right)$$

can be readily deduced. In this K is the conductivity of ice, ρ is the density of ice; L is the latent heat of fusion; θ, the temperature of air; x, the distance the ice has attained at a time t, and lo, an expression giving the boundary conditions between ice and water.

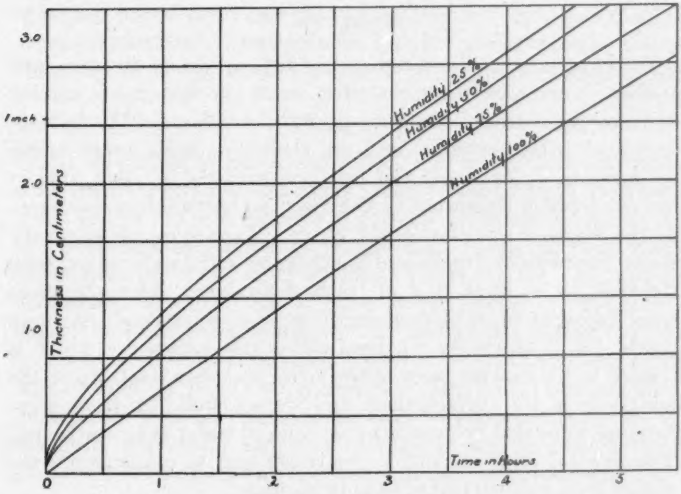

FIG. 2.

Instead of deducing a general equation with terms involving all the quantities which enter into the growth of ice, it is better to take each separately and determine its effect on the general equation. Thus the fact that water under the ice is usually one or two hundredths of a degree above freezing means that the convection currents bring about the limiting thickness. It is possible to arrange in the form of a diagram, Fig. 1, a simple means of finding the limit-

ing thickness to which surface ice will grow, having given the condition of mean air and water temperature. The condition of no ice may exist and the boundary showing the limit of the ice is shown where the lines cut the vertical axis of temperature.

The effect of evaporation I have already discussed. Fig. 2 illustrates the effect of different degrees of humidity on the rate of growth of ice. The effect of radiation on the growth of surface ice is small and not easily determined, and may for simplicity be included with that due to convection; but, although so important a factor in the formation of anchor ice, it is unimportant considered with reference to producing surface ice growth.

FRAZIL ICE.

Wherever a river flows too swiftly for surface ice to form into a sheet, it remains disintegrated in small crystals and is carried down by the current. On account of the smallness of the crystals they have little buoyancy and are, therefore, easily swept under by currents. The amount of frazil, as such ice is called, that is formed depends somewhat on the mean air temperature, but more on the degree of agitation of the water. Thus in rapids where the water tumbles over rocks and is otherwise intimately mixed with the cold air, a great deal of frazil is produced, which becomes troublesome at times and causes winter and spring floods on many rivers. It is swept by currents under the surface ice which is formed in the quieter parts of the river, and then floats up to the underside of the surface sheet and freezes, building down great hanging dams that become as impervious to water as so much rock. The natural river channel is restricted and in consequence the winter level is much higher than in summer.

I have shown* that this ice is formed most rapidly on the surface, but it appears also throughout the body of the river when the water is supercooled. The supercooling is never more than a few thousandths of a degree, but notwithstanding this it produces great physical effects. It is during such a time that the ice becomes adhesive, agglomerated, and produces trouble to the operators of water powers. The strength and tenacity of the frazil as

* "Ice Formation."

long as the temperature remains below the freezing point is enormous. It wants but the very smallest change of temperature in the water, however, to make it soft and spongelike and easily disintegrated.

The sun is the most powerful agent in imparting the necessary small fraction of temperature to the water to relieve ice troubles. Thus water wheels which have been securely cemented during the night are soon running again the next day when the sun comes out.

Artificial methods of heating have been developed which have proved remarkably successful. The most effective methods are those of Mr. John Murphy, E.E., of Ottawa, who has been studying the problem for many years. There is now no reason why any power plant operated by hydraulic means should suffer from ice troubles. This has been brought about through a careful study of the physical laws underlying the formation of ice.

ANCHOR-ICE.

The formation of ice on the bed of a river which is not frozen over has been observed for many years. Many names have been given to this ice. In America it goes by the name of anchor-ice, but in Europe by bottom or ground ice. There has been much discussion over the cause of the formation of this ice. It has now been widely accepted that it grows on the surface of objects immersed in water which is slightly supercooled and flowing too fast to freeze over. On clear, cold nights it is found growing more rapidly than on cloudy ones, and it is observed to form on dark rocks faster than on light-colored ones. Terrestrial radiation is, therefore, responsible for much of the ice, and in addition vast quantities of frazil crystals are frozen to the bottom-ice after having been carried down by currents. With the water above the freezing point no anchor-ice can form, and it has never been observed to grow on the bottom under surface ice. Whenever it has formed previous to surface ice it is dislodged as soon as the cover forms, and rises up to become attached to the underside of the surface sheet.

The sun has a powerful influence in preventing anchor-ice formation, and in melting it off when once it has formed. It is a well-known sight along the St. Lawrence, on a clear, cold morning

in winter, to find great masses of ice rising from the bottom as soon as the sun's rays can penetrate into the water. These masses have been attached to the ground, and by growing in size have exerted greater and greater buoyant force on the rocks. Some of them come up bringing masses of rock with them purely by their own force, but the warm penetrating rays of the sun soon clear the bottom. The masses come up with such force that they often protrude high out of the water, resembling great dark masses of earth, turning white as the water drains out. Soon the whole surface of the river is dotted thickly by these white patches of varying size, floating down with the current. The natives along the river call the masses "haycocks of ice," a name quite appropriate to this form of soft ice. Boatmen on the river are very careful not to go out when the ice is rising, for fear of being surrounded or upset by masses of this ice rising under the boat. In Russia a great deal of time has been devoted to the study of anchor-ice, and the floods caused by the packing of such ice carried down by the currents. In many respects the conditions on the Neva are quite similar to those on the St. Lawrence. It is an interesting point to be observed that the Russian engineers detailed to study the question of winter floods on the Neva have reported along a line exactly similar to the report of the Montreal Flood Commission in 1886. It is pointed out how useless it is to try and combat the ice packs after they are formed, but that every effort should be made in the early stages to prevent them from forming, by means of ice breakers. The water channel must be kept open to allow of a free runway of the ice to tide water, and by this means only can floods be prevented. In conclusion it may be said that there is much to be gained by an active study of ice and methods of prevention on our lakes and rivers. The results have so far been surprising, but a much greater gain may be looked for in the future.

DOUBLE FILTRATION OF WATER.

BY H. W. CLARK, CHEMIST, MASSACHUSETTS STATE BOARD OF HEALTH.

[*Read March 9, 1910.*]

It is a trite saying in regard to surface water supplies that the thing to do is to obtain the best supply of water possible and then filter it, and this is the advice given by many experts upon water supply and water purification and by students of typhoid epidemics. The demand for filtered water or water purified in some way other than filtration has not only been the cause for much scientific research by men who make this subject their life study, but has also encouraged a large number of men engaged in other walks of life, either together or singly, to devise methods that they believe may improve water and which they know will improve their bank account if an unsuspecting public can be persuaded to adopt these methods and their appliances. A number of such schemes come under my observation and investigation nearly every year, and here and there one or another of them has been adopted temporarily. There are to-day two widely known methods of water purification; one, plain sand filtration, and the other, mechanical filtration with the aid of coagulants and such other chemicals as modern experience and necessity suggest may with advantage be used to kill bacteria and thus aid the efficiency of the purification system. We hear a great deal at present about the use of hypochlorite of lime as an aid to mechanical filtration, and its use alone with certain reservoir waters, and the method of treating waters with ozone before filtration is again coming to the front, whether because of its merits or because of its persistent advocates, the future will show. There are, also, so-called electrolytic methods of water purification in which the electric current is stated to act as a bactericide but which in the devices I have examined, simply causes the taking of aluminum from aluminum or composition electrodes and the formation of alumi-

num hydrate, — really an expensive method of coagulation. The purification of water by plain sand filtration is an easy task when the waters treated are not too seriously polluted by suspended matter or organic matter and bacteria, and the question of double filtration only comes to the front when pollution is great or when, owing to the turbidity of the water, it may apparently be of advantage from an economic point of view to subject it to a preliminary filtration or other treatment at a high rate before passing it to the slow sand filtration beds. Double filtration has also been suggested for use where reservoir waters are subject to large growths of organisms causing their characteristic tastes and odors, and such filter plants have been partially constructed at South Norwalk, Conn., and Bar Harbor, Me.

Studies on double filtration of Merrimac River water were begun at the Lawrence Experiment Station in 1894. In the fall of 1893, the Lawrence city filter had been put into operation and it was deemed important to determine just how far the purification so well begun in the city filter could be carried by passing the filtered water through additional sand filters. In the passing years the fact has been lost sight of that when the construction of the Lawrence filter was urged by the Massachusetts State Board of Health, it was stated by the board that double filtration of the river water might be necessary, and in May, 1894, filtered city water was applied to five experimental sand filters which had been previously operated with polluted water. Two of these filters contained less than one foot in depth of sand, one about two feet, and the other two about five feet in depth of sand. The material in the shallow filters was of about the same grade as that ordinarily used in slow sand filters, but that in the two deeper filters was somewhat coarser, more like the sand now used in mechanical filters or preliminary filters intended to be operated at high rates. The three shallow filters were operated at rates of from 2 000 000 to 3 000 000 gallons per acre daily, and the two deep filters were operated comparatively at rates of 2 500 000 and 5 000 000 gallons per acre daily, respectively.

Notwithstanding the fact that this water had passed through the city filter, had been stored about six weeks in the distributing reservoir, and had passed through about two miles of street

mains, during which processes a material reduction had been made in the small numbers of bacteria remaining after its initial filtration, still when the water was filtered a second time through a filter containing but ten inches in depth of sand, a very considerable improvement in its bacterial quality was produced, for as shown in an accompanying table, from 65 to 85 per cent. of the few bacteria in the water applied to these filters was removed. Tests made by adding cultures of special types of bacteria (*B. prodigiosus*) to the applied water showed, furthermore, that the elimination of such test types was even greater, or more than 99.6 per cent.

These early experiments proved that filtration processes could be effectively applied over and over, and that so long as anything remained in the water which could be removed, a further filtration would produce a certain improvement in the quality of the water, and gave rise to the belief that higher rates, or greater economy of operation, might be effected by double filtration methods.

EXPERIMENTAL FILTERS RECEIVING FILTERED WATER.

Effective Size of Sand.	Depth of Sand. (Inches.)	Rate. Million Gallons per Acre Daily.	Bacteria per Ccm. in Effluent.	Bacterial Efficiency.
.20	10	2.0	52	45.3
.20	10	3.0	30	72.7
.20	24	3.0	15	86.4
.29	20	2.5	35	68.2
.35	58	2.5	18	81.6
.35	58	5.0	18	81.6

Experiments on double filtration of water even more seriously polluted by sewage than Merrimac River water were made at Lawrence about fifteen years ago. In May, 1896, two filters were put into operation receiving such water, and the average rate of operation of these filters throughout the year was slightly more than 1 000 000 gallons per acre daily. They received water containing twice as much organic matter as was present in the Merrimac River and twenty times as many bacteria. One of these filters was operated continuously and the other intermittently, and the average removal of bacteria was 75 and 92 per cent., respectively. The much greater efficiency of the intermittent filter was due to the great pollution of the water and the necessity,

if good results were to be obtained, of such additional air supply as intermittent filtration gives. During the last four months of their operation, the bacterial efficiency of the filters was 96.5 and 98.5 per cent., respectively. Even then, however, the effluents of these filters contained nearly as many bacteria as were present in Merrimac River water, and refiltration through a secondary filter was begun in September, 1896. This secondary filter was at least three months in getting into good working operation, but at the end of the third month its efficiency was about 90 per cent. and it was producing a water having about 350 bacteria per ccm. when operating at a rate of about 4 000 000 gallons per acre daily. The operation of this filter made it clear that water after a primary filtration was so free from organic matter that a secondary filter gained its normal bacterial efficiency very slowly.

This particular investigation was continued for five years and is summarized in the Lawrence Experiment Station report for 1900, where it is shown that the two preliminary filters during their entire period of operation removed about 98 per cent. of the bacteria present in the polluted water applied, leaving effluents, however, containing several hundred bacteria per ccm., and the secondary filter operating at a rate of about 2 500 000 gallons per acre daily removed 96.5 per cent. of the bacteria in the applied effluents and produced a water containing only 60 bacteria per ccm. With the very polluted water dealt with, the rates of operation were necessarily low, and about three acres of filter surface would have been necessary to produce 1 500 000 gallons of purified water per day. From time to time after this, other investigations of a similar nature were made that I will not summarize here. For the past three years, however, a series of filters has been operated at the station to test the efficiency of such filters when operating under varying rates and the efficiency of double filtration when treating a water similar to that flowing in the Merrimac River at Lawrence. The following table shows the results obtained when filtering Merrimac River water through practically duplicate filters operating at rates of from 3 000 000 to 16 000 000 gallons per acre daily. The results shown in the table are an average of nearly two years' work and of many hundred bacterial analyses of each effluent.

Effective Size of Sand.	Filter No.	Rate. Gallons per Acre Daily.	Bacteria per Ccm. in Effluent.	Bacterial Efficiency.	B. Coli in 1 Ccm. (Per Cent. of Positive Tests.)
.28	A	3 000 000	48	99.1	5.0
.25	B	5 000 000	85	98.4	24.0
.22	C	7 500 000	105	98.1	25.0
.22	D	10 000 000	110	98.0	25.0
.22	E	16 000 000	280	95.0	38.0

Operating at these rates the efficiencies varied from 99.1 to 95 per cent., and the number of bacteria in the respective effluents from 48 to 290 per ccm. In regard to the result of the filter operating at the highest rate and the probable effect of the use of such a water, it can be said that before the city of Lawrence filtered its water supply, the water when passing through the city reservoir, which holds about 40 000 000 gallons, lost about 94 per cent. of the bacteria present, and yet this water caused epidemics of typhoid fever. It will be noticed, also, that the hygienic efficiency, or B. coli removal of the filters, decreased very rapidly as the rate of the filters increased, much more rapidly than the bacterial efficiency. The water applied to these filters contained generally from 100 to 500 B. coli per ccm., while in the effluents from the best filter, only 5 per cent. of the 1 ccm. samples tested for B. coli showed the presence of this germ. The experience of many years at Lawrence has shown that an efficiency such as given by the best filter represented on the table is an absolute protection to a city using such water as that flowing in the Merrimac River and filtered through sand.

The question then arose: Can an equally good result be obtained by double filtration with these two filters operating at such rates that a greater volume of purified water per acre of filter surface can be secured?

During the past three years five double filtration systems have been in operation at the station to answer this question, and the results of three of them are given here. All of these filters were ordinary sand filters containing about 40 inches in depth of sand. In the first system the rates of operation were 10 000 000 and 20 000 000 gallons per acre daily, respectively, the rate of the primary filter being smaller than that of the secondary filter; in the second system the rates were 23 000 000 and 7 500 000 gallons per

acre daily, respectively, the rate of the primary filter being greater than that of the secondary filter; and in the third system, both filters were operated at equal rates, namely, 6 000 000 gallons per acre daily. The net rate of each system was 6 600 000, 6 000 000 and 3 000 000 gallons, respectively; that is, the volume of water filtered per acre of filter surface used. It seemed during the first few months of this work that greater efficiencies could be obtained by double filtration than by single and with the production of a greater volume of purified water per acre of filter. Taken as a whole, however, the results were as follows: Neither the first nor the second system gave results quite equal to the single filters shown on the previous table operating at a rate of 5 000 000 gallons per acre daily; neither did either system give results in coli efficiency equal to the single filter operating at the rate of 7 500 000 gallons per acre daily. With the system, however, operating at a net rate of 3 000 000 gallons per acre daily, the results were practically the same as with the single filter operating at a rate of 3 000 000 gallons per acre daily. It is difficult to state just why this double filtration through much greater depths of sand than in use with the single filter does not always give better results than single filtration. One important reason seems to be, however, that the rate of the primary filter has generally been too great for good bacterial efficiency to occur; yet by this primary filtration the organic matter necessary to cause the secondary filter to be an efficient water purification plant has been removed. While we have some results differing from those presented here, still it does not seem reasonable to assume from all the results of Lawrence work that water of the character of that flowing in the Merrimac River can be purified more advantageously or more economically, as far as net product of filtered water is concerned, by double filtration systems than by a single filter operating at a reasonable average rate.

There is, of course, another reason that has been prominently mentioned for the operation of primary filters, and that is to lessen the area upon which the matter in suspension in the raw water is collected. This is a very prominent feature in the beginning of operation of such systems, especially when the primary filters are operated at rates approximating 100 000 000 gallons

per acre daily. It always seems at first that much can be gained in this way; yet as these systems of double filtration are kept in operation at Lawrence, although the water passing to the secondary filter may remain free from matters in suspension, this secondary filter becomes an efficient biological machine, the sand grains throughout its depth become coated with the gelatinous matter necessary for this efficiency, and eventually these secondary filters at Lawrence require scraping almost as frequently and as deeply as if they were receiving raw water without primary filtration.

This, then, must be the conclusion from our Lawrence work: There is little to gain either in economy in sand removal or sand washing, or in bacterial efficiency, in double over single filtration of polluted water such as flows in the Merrimac River, that is, with an equal or nearly equal production of filtered water per acre of filter surface. We realize, of course, that each water presents a separate problem, and Lawrence results are not universally applicable.

SOME WATER-WORKS STATISTICS AND TYPICAL DATA SHOWING RATE OF ACQUISITION OF INCOME FOR DOMESTIC SERVICE BY DIFFERENT CLASSES OF RESIDENTIAL PROPERTY.

BY FRANK C. JORDAN, SECRETARY OF THE INDIANAPOLIS WATER COMPANY.

[*Read September 22, 1910.*]

A month or two ago, Mr. Leonard Metcalf requested the writer to prepare a paper for your Association on the topic "Statistics of the Growth of Income." What he had in mind, I believe, was not the general growth of income of water-works plants, but more particularly the growth of income from domestic service upon individual lines, such lines to be fairly representative of the different sections of a city.

From the standpoint of investment, there are always, in connection with water-works service, districts which do not contribute their share of income, and these districts must be taken into account in making up a general average or in determining proper rates for domestic service. Before giving the results of the studies and investigations, I wish to state that I have called upon and addressed several of the water departments and water companies throughout the Central West but have been unable to obtain any information of value from them along this line, the general statement being that the growth of income on individual lines in the residential districts is usually slow. For this reason we shall be unable to make comparisons which would make this paper more valuable.

The writer has selected pipe-lines in different districts in the city of Indianapolis, Ind., the income from which is assumed to be about the average, or typical of the assumed classification. In making this study, the city naturally divides itself into about the following districts:

1. The cheap district in the outlying portion of the city.
2. The district between middle and cheap class in the outlying portion of the city.

3. The district between middle and cheap residential in the heart of the city.

4. The cheap residential district in the heart of the city.

5. The high-class residential district annexed to the city after the district has been very well built up.

6. The best residential district in the outlying portion.

7. The best residential district in the heart of the city.

As before stated, this paper will deal with one city only, viz., the city of Indianapolis and the Indianapolis Water Company, with which the writer is connected. This company has in its distribution system 325 miles of pipe, the average diameter of which is in excess of 10 inches; 25 000 taps in service supplying between 29 000 and 30 000 dwellings, business blocks, factories, etc. In this connection we wish also to state that the rates charged for water, which have a direct influence upon income, are somewhat less in Indianapolis than those of the average city of its size supplying water under like conditions. We have on our lines, in round numbers, 55 000 buildings of various kinds, of which 55 per cent. are supplied with water by our company. From what we are able to learn from other cities similarly situated, we find that this percentage is lower than in the average city of our class.

On the first district mentioned above, viz., the cheap district in the outlying portion of the city, we found that the revenue per mile of pipe at the end of the first year was $140; at the end of the second year, $200, and that there was very little change in this revenue during the fifteen years following the laying of these lines.

On the lines in the second district, viz., that district between the middle and cheap class in the outlying portion of the city, we found that the revenue was $170 at the end of the first year; at the end of the second year, $260; at the end of the third year, $300; at the end of the tenth year, $340, and that this increase of rate was maintained during the years following the laying of these lines.

On the lines in the third district mentioned, that district between the middle and cheap residential in the heart of the city, it was found that the revenue per mile of pipe at the end of the first year was $250; at the end of the second year, $380; at the end of the

fifth year, $610; at the end of the tenth year, $750, and at the end of the fifteenth, $850.

The growth in income in the fourth district, or the cheap residential district in the heart of the city, was found to be fairly satisfactory. The revenue per mile of pipe in this district was $310 at the end of the first year; $560 at the end of the second year; $740 at the end of the third year; $1 020 at the end of the fifth year, after which the growth was not so marked.

On the lines in the high-class residential district annexed to the city after having been fairly well built up, we found a satisfactory growth, the revenue being $360 at the end of the first year; $560 at the end of the second year; $860 at the end of the fifth year; and this rate of increase was maintained during the years following the laying of these lines.

These investigations indicate that the best residential district in the outlying portion of the city contributes more that the average share of the expense of supplying water. The revenue on the lines in this district was $400 at the end of the first year; $670 at the end of the second year; $1 260 at the end of the fifth year; $2 200 at the end of the tenth year. These lines show a steady increase from year to year.

The average revenue on lines in the best residential district in the heart of the city at the end of the first year was $800; at the end of the third year, $1 570; at the end of the fifth year, $1 930, after which the growth was exceedingly slow for the next ten years, during which time the property was changing from a residential district to a district of flats and apartment houses, with some of the better class of boarding houses. Following this transitory period, the revenue began to increase, reaching $3 060 per mile at the end of twenty years.

It will be noted from Fig. 1 that the growth of income on all lines in outlying districts is slow for the first few years, but the growth is fairly constant throughout the periods as shown; also that the growth of income in the central or thickly populated part of the city is rapid in the beginning, but after the first four or five years there is but a slight increase of income. The reason for this will be apparent to the water-works superintendent or engineer from the fact that in the outlying district the houses are more or

less scattered in the beginning and the income increases according to the increased building along the service line. It will be seen further that the income of but few districts is equivalent to the fixed charges on the lines laid, for the first two or three years; also that the poorer districts do not pay the fixed charges on the

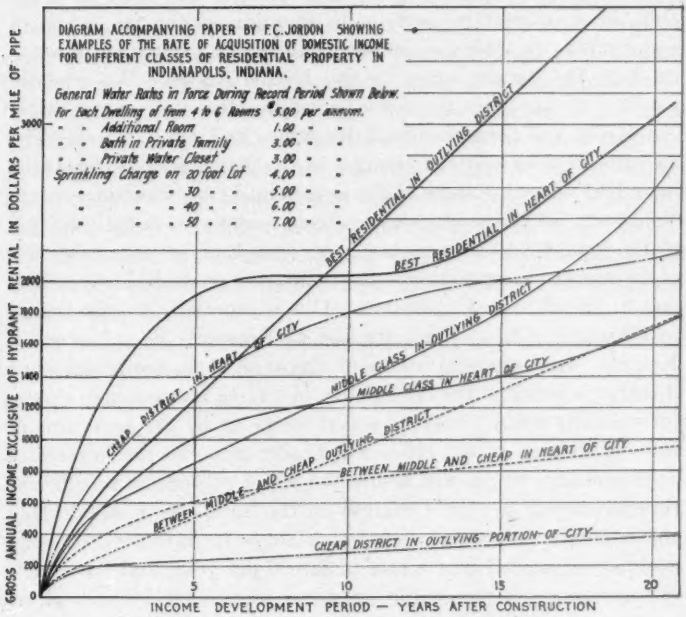
DIAGRAM ACCOMPANYING PAPER BY F.C. JORDON SHOWING EXAMPLES OF THE RATE OF ACQUISITION OF DOMESTIC INCOME FOR DIFFERENT CLASSES OF RESIDENTIAL PROPERTY IN INDIANAPOLIS, INDIANA.
General Water Rates in Force During Record Period Shown Below.
For Each Dwelling of from 4 to 6 Rooms $3.00 per annum.
Additional Room 1.00
Bath in Private Family 3.00
Private Water Closet 3.00
Sprinkling Charge on 20 foot Lot 4.00
30 5.00
40 6.00
50 7.00
GROSS ANNUAL INCOME EXCLUSIVE OF HYDRANT RENTAL IN DOLLARS PER MILE OF PIPE
INCOME DEVELOPMENT PERIOD — YEARS AFTER CONSTRUCTION
BEST RESIDENTIAL IN OUTLYING DISTRICT
BEST RESIDENTIAL IN HEART OF CITY
MIDDLE CLASS IN OUTLYING DISTRICT
MIDDLE CLASS IN HEART OF CITY
CHEAP DISTRICT IN HEART OF CITY
BETWEEN MIDDLE AND CHEAP IN HEART OF CITY
BETWEEN MIDDLE AND CHEAP OUTLYING DISTRICT
CHEAP DISTRICT IN OUTLYING PORTION OF CITY

FIG. 1.

lines even after the lines have been laid for ten or fifteen years. This point is frequently overlooked in connection with proposed extensions, as, on account of fire protection, it is necessary, to a certain extent, that all parts of the city shall be served.

The variation in the number of consumers on these lines in the districts is an interesting study. In the best residential district, we are supplying 87 per cent. of the properties adjacent to our lines, while in some of the poorer districts we are supplying only from

8 per cent. to 12 per cent. A map showing the percentage of properties supplied in different districts has been of considerable value to us, particularly regarding the advisability of laying certain proposed extensions.

In Mr. Metcalf's letter to the writer, it was suggested that in connection with the notes on the growth of income, it would probably be of interest to make some mention of our tabulation of water rates. In 1908 the company published a tabulation of water rates in the various cities in the United States. We recently received at our office the latest schedules from the various water companies and departments throughout the United States. The changes in rates and the changes in the attitude of water-works managers regarding some of the important issues were interesting. Practically all of the cities which have recently installed filtration plants have found it necessary to increase their rates to take care of the increased expenditures due to interest on capital investment and to added cost of operation. This is especially true in regard to Columbus, Ohio; Pittsburg and McKeesport, Pa.; Louisville, Ky., etc. In the annual reports of almost all of the companies some mention is made of the desirability of having a reasonable charge for standing ready to serve, and it seems to be the concensus of opinion that all of the cities will finally agree to the fairness of such a charge which will assure the water companies a sufficient revenue to pay the fixed charges on the lines. In going through the schedules we found very few changes in flat rates, it being generally conceded that a rate of $18.00 per year, under ordinary circumstances, is reasonable for water service for a house of six or seven rooms with all the modern conveniences in the way of bath, toilet, laundry trays, sprinkling connection, etc. A number of the cities have made slight changes in their meter rates, and a revision of the tabulation shows that the average maximum rate per one thousand gallons for water by meter measurement is 22.8 cents and the minimum rate is 9 cents. The Manufacturers' Association of St. Louis recently tabulated some information from 23 cities and found that the average minimum rate was 7 cents per one thousand gallons. Their tabulation, however, took into account only the larger cities such as Detroit, Cleveland, Buffalo, New York, etc. In making a study of the schedules of

rates in connection with the reports of the various departments which give an idea of the problems confronting water departments in these various cities, it becomes apparent that it is obviously unfair to strike an average water rate for all cities and then limit a certain city to that rate. A comparison of rates will be found to be of considerable interest, but the fact must be borne in mind that each city has its individual conditions which must be given due weight, and a rate which is fair in one city may, on account of different conditions, be absolutely unfair in a neighboring city.

In reading the various messages from the mayors of the cities to their respective water departments, it will be noted that the municipalities are reaching the conclusion that the first and foremost essential is the furnishing of a first-class supply of good water suitable both for commercial and domestic purposes, to be followed by water rates sufficient to operate and maintain the plant as a whole, as well as to take care of depreciation, and give a fair return on the investment.

As before stated, the appended tabulation was prepared for purposes of direct comparison.

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons.	
		Municipal.	Private.	House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
Birmingham, Ala.	132 685	..	P	$11.00	$5.00	$4.00	....	....	.....	$20.00	$0.30	$0.05
Mobile, Ala.	51 521	M	..	6.50	2.75	1.00	$1.00	....	$4.00	15.25	.15	.03½
Ft. Smith, Ark.	23 505[1]	..	P	8.00	2.00	2.00	....	....	5.00	17.00	.25	.10
Little Rock, Ark.	45 941	..	P	5.50	4.00	4.00	....	....	8.00	21.50	.30	.05
* Los Angeles, Cal.	319 198	M	..	10.20	1.80	1.80	....	....	4.32	18.12	.09½	.09½
San Diego, Cal.	39 578	M	..	15.60	3.00	3.00	....	....	4.80	26.40	.10	.06
San Francisco, Cal.	416 912	..	P	4.32	3.84	2.64	.60	....	8.00	19.40	.33	.16
San José, Cal.	28 946	..	P	9.60	1.80	4.80	....	....	8.00	24.20	....	....
Stockton, Cal.	19 354[1]	..	P	8.40	1.80	1.80	....	....	7.80	19.40	.25	.10
Colorado Springs, Col.	29 078	M	..	12.00	1.00	2.00	....	....	8.00	23.00	.15	.06
Denver, Col.	213 381	..	P	4.30	3.60	3.60	....	....	8.80	20.30	.17	.10
† Pueblo, Col.	44 395	M	..	18.00	6.00	6.00	....	....	No rate	30.00	.25	....
Bridgeport, Conn.	102 054	..	P	6.00	5.00	4.00	....	....	4.50	19.50	.18	.04
Hartford, Conn.	98 915	M	..	All metered			....	....	.....	.....	.16	.08
Meriden, Conn.	27 265	M	..	5.00	2.00	3.00	....	....	3.00	13.00	.15	.10
* New Britain, Conn.	43 916	M	..	5.00	3.50	3.50	.50	....	3.50	16.00	.10	.05
New Haven, Conn.	133 605	..	P	5.00	3.00	3.00	....	....	6.80	17.80	.18	.10
New London, Conn.	19 882[1]	M	..	4.50	2.00	2.00	....	....	12.50	21.00	.16	.06
Norwich, Conn	19 759[1]	M	..	5.00	3.00	3.00	....	....	3.40	14.40	.27	.06
Waterbury, Conn.	73 141	M	..	5.00	2.00	3.00	....	....	3.00	13.00	.20	.10
Wilmington, Del.	87 411	M	..	5.00	3.00	2.00	1.00	1.00	3.00	15.00	.10	.04¾
Washington, D. C.	331 069	M	..	.....	....	....	....	....	.....	.....	.04	.04
Jacksonville, Fla.	57 699	M	..	All metered			....	....	.....	.....	.10¾	.05½
Pensacola, Fla.	22 256[1]	..	P	8.00	6.00	6.00	2.00	By meter only		22.00	.50	.15
*Tampa, Fla.	38 524	..	P	8.00	5.00	4.00	2.00	....	8.00	27.00	.22½	.12
Atlanta, Ga.	154 839	M	..	All metered			....	....	.....	.....	.10	.07
Augusta, Ga.	37 826	M	..	5.00	3.00	2.00	1.00	3.00	5.00	19.00	.10	.04
Macon, Ga.	40 665	..	P	6.50	5.00	5.00	3.00	3.00	12.00	34.50	.30	.06
Savannah, Ga.	65 064	M	..	.....	....	....	....	....	.....	13.50	.12½	.08

Alton, Ill.	.....	..	P	6.00	4.00	3.00	....	....	4.00	17.00	.28	.06
Aurora, Ill.	29 807	M	..	All metered			....	....	.....	.....	.48	.05
Bloomington, Ill.	25 768	M	..	All metered			....	....	.....	.....	.25	.25
Chicago, Ill.	2 185 283	M	..	.....	....	....	....	....	.....	.....	.07	.07
Danville, Ill.	27 871	..	P	5.50	2.50	2.50	0.50	....	6.50	17.50	.25	.10
Decatur, Ill.	31 140	M	..	5.00	3.00	2.50	....	....	6.00	16.50	.10	.04
East St. Louis, Ill.	58 547	..	P	6.00	5.00	5.00	....	....	6.00	22.00	.30	.10
Elgin, Ill.	25 976	M	..	5.00	5.00	2.50	....	....	3.00	15.50	.25	.07
Evanston, Ill.	22 949 [1]	M	..	4.00	3.30	3.30	....	....	3.80	14.40	.16	.08
Joliet, Ill.	34 670	M	..	.....	....	....	....	....	.....	14.50	.12	.05
Peoria, Ill.	66 950	..	P	6.00	3.00	3.00	1.50	....	5.00	18.50	.20	.06
* Quincy, Ill.	36 587	..	P	5.40	4.28	4.50	.45	....	7.92	22.55	.45	.06
Rock Island, Ill.	23 009 [1]	M	..	6.00	3.00	3.00	....	....	3.00	15.00	.20	.06
Rockford, Ill.	45 401	M	..	5.00	2.00	2.50	....	....	5.00	14.50	.16	.08
Springfield, Ill.	51 678	M	..	4.00	2.40	2.40	2.40	2.40	8.00	21.60	.25	.06
Anderson, Ind.	25 842 [1]	M	..	4.00	2.50	2.50	2.50	....	4.40	15.90	.15	.05
Clinton, Ind.	.....	M	..	5.00	3.00	3.00	....	....	5.00	16.00	.30	.15
Crawfordsville, Ind.	.....	..	P	6.00	3.00	3.00	.50	....	3.20	15.70	.30	.10
Elkhart, Ind.	17 501 [1]	..	P	.....	....	....	....	....	.....	16.00	.12	.08
Elwood, Ind.	19 232 [1]	..	P	6.00	5.00	5.00	2.00	3.00	5.00	26.00	.25	.07
Evansville, Ind.	69 647	M	..	5.00	2.00	4.00	1.00	2.00	1.50	15.50	.20	.05
Ft. Wayne, Ind.	63 933	M	..	4.40	3.20	2.40	.40	....	6.40	16.80	.10	.06½
Franklin, Ind.	.....	..	P	6.00	2.00	2.00	2.00	....	5.00	17.00	.40	.20
Greencastle, Ind.	.....	..	P	6.00	4.00	5.00	2.00	2.00	5.00	24.00	.30	.30
Greensburg, Ind.	.....	..	P	6.00	3.50	3.00	1.00	....	5.00	18.50	.35	.15
Lafayette, Ind.	19 238 [1]	M	..	5.75	3.50	2.50	1.00	....	5.00	17.75	.20	.06
Linton, Ind.	.....	..	P	7.20	3.00	4.00	....	....	6.00	20.20	.35	.07
*Marion, Ind.	24 030 [1]	M	..	4.44	2.22	2.78	.55	....	3.20	13.19	.15	.06
Michigan City, Ind.	17 292 [1]	..	P	2.00	2.00	2.00	3.00	2.00	6.00	17.00	.06	.05
Mt. Vernon, Ind.	.....	..	P	5.50	3.50	3.00	....	....	4.00	16.00	.40	.09
New Albany, Ind.	20 628 [1]	..	P	6.65	2.85	1.90	1.90	.95	4.50	18.75	.13½	.04½
New Castle, Ind.	.....	M	..	.....	....	....	....	....	.....	.....	.10	.08
Noblesville, Ind.	.....	..	P	5.00	5.00	5.00	....	....	5.00	20.00	.60	.10
Richmond, Ind.	19 602 [1]	..	P	6.00	5.00	3.00	.50	....	3.42	17.92	.25	.06
Seymour, Ind.	.....	..	P	5.75	3.00	3.50	3.00	....	7.00	22.25	.40	.06
Shelbyville, Ind.	.....	..	P	5.00	2.50	2.50	2.50	....	3.20	15.70	.30	.10
So. Bend, Ind.	53 684	M	..	4.50	3.00	2.00	1.50	....	3.80	14.80	.12	.08
Terre Haute, Ind.	58 157	..	P	5.00	3.00	3.00	....	....	5.50	16.50	.30	.08
Valparaiso, Ind.	.....	..	P	7.00	4.00	4.00	2.00	2.00	5.00	24.00	.30	.15
Vincennes, Ind.	11 393 [1]	..	P	6.00	5.00	5.00	....	1.00	7.00	24.00	.25	.10
Wabash, Ind.	9 944 [1]	..	P	6.00	4.00	3.00	....	....	5.50	18.50	.33	.06⅔
Winchester, Ind.	.....	..	P	6.00	3.00	3.00	....	....	3.00	15.00	.25	.07

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910. — *Continued.*

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons.	
		Municipal.	Private.	House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
Burlington, Ia.	25 741 [1]	..	P	$6.00	$5.00	$4.00	....	....	.....	$15.00	$0.25	$0.05½
Cedar Rapids, Ia.	32 811	M	..	6.50	3.00	3.00	....	....	$3.30	15.80	.25	.08
Clinton, Ia.	25 577	..	P	6.00	5.00	3.00	....	....	5.00	19.00	.30	.06
Council Bluffs, Ia.	29 292	..	P	7.00	3.00	3.00	....	$2.00	5.00	20.00	.33	.08
Davenport, Ia.	43 028	..	P	6.00	3.50	4.50	$0.90	.90	4.50	20.30	.33	.11⅓
Des Moines, Ia.	86 368	..	P	4.00	3.00	3.00	....	....	7.50	17.50	.30	.10
Dubuque, Ia.	38 494	M	..	6.00	3.00	3.00	....	....	5.00	17.00	.25	.11
Ottumwa, Ia.	20 548 [1]	..	P	8.00	5.00	5.00	....	....	5.00	23.00	.30	.10
Sioux City, Ia.	47 828	..	..	All metered			....	....	.....	.....	.25	.10
Atchison, Kan.	18 871 [1]	..	P	5.60	3.50	3.70	....	....	4.00	16.80	.30	.10
Kansas City, Kan.	82 331	..	P	5.00	4.00	4.50	....	....	6.80	20.30	.25	.05
Leavenworth, Kan.	.....	..	P	9.00	5.00	5.00	....	....	10.00	29.00	.50	.20
Topeka, Kan.	43 684	M	..	6.00	5.00	3.00	....	....	6.00	20.00	.50	.11¼
Covington, Ky.	53 270	M	..	All metered			....	....	.....	.....	.19	....
Lexington, Ky.	35 099	..	P	All metered			....	....	.....	.....	.25	.10
Louisville, Ky.	223 928	M	..	6.00	5.00	3.00	1.00	.50	6.50	22.00	.15	.06
Newport, Ky.	30 309	M	..	6.00	6.00	3.00	2.00	2.00	3.60	22.60	.15	.10
Paducah, Ky.	22 464 [1]	..	P	6.16	3.55	3.30	.70	....	6.50	20.21	.25	.06
New Orleans, La.	339 075	M	..	.....	.....	.....	.....	.....	.....	.....	.10	.10
Bangor, Me.	23 500 [1]	M	..	5.00	3.00	3.00	3.00	1.00	3.00	18.00	.07⅓	.07⅓
Lewiston, Me.	26 217	M	..	5.00	2.00	1.50	....	1.00	2.00	11.50	.25	.20
Portland, Me.	58 571	M	..	.....	.....	.....	.....	.....	.....	.....	.26⅔	.09⅓
Baltimore, Md.	558 485	M	..	.....	.....	.....	.....	.....	.....	.....	.08	.04
Boston, Mass.	670 585	M	..	7.00	....	5.00	....	....	5.00	17.00	.18⅔	.10⅔
Brockton, Mass.	56 878	M	..	All metered			....	....	.....	.....	.22⅔	.13⅓
Cambridge, Mass.	104 839	M	..	4.00	4.00	3.00	2.00	2.00	5.00	20.00	.20	.10
Chelsea, Mass.	32 452	M	..	6.00	....	5.00	....	....	5.00	16.00	.18⅔	.10⅔
Everett, Mass.	33 484	M	..	7.00	....	5.00	....	....	5.00	17.00	.18⅔	.10⅔
‡ Fall River, Mass.	119 295	M	..	5.00	5.00	5.00	2.50	....	6.00	22.00	.28	.10
Fitchburg, Mass.	37 826	M	..	5.00	4.00	4.00	1.50	....	4.50	19.00	.18	.04

Gloucester, Mass.	25 989[1]	M	..	6.00	6.00	6.00	3.00	3.00	5.00	29.00	.30	.15
Haverhill, Mass.	44 115	..	..	5.50	3.00	4.00	....	....	5.00	17.50	.21½	.10
* Holyoke, Mass.	57 730	M	..	3.00	2.00	2.40	....	....	4.80	12.20	.05⅔	.05⅔
Lawrence, Mass.	85 892	M	..	5.00	3.00	4.00	....	....	3.25	15.25	.20	.08
Lowell, Mass.	106 294	M	..	6.00	3.00	4.00	1.00	1.00	3.00	18.00	.18¾	.13¼
Lynn, Mass.	89 336	M	..	5.00	3.00	3.00	1.00	1.00	4.00	17.00	.20	.17½
Malden, Mass.	44 404	M	..	All metered			....	....	.....	.....	.21⅓	.13¼
New Bedford, Mass.	96 652	M	..	All metered			....	....	.....	.....	.15	.10
Newton, Mass.	39 806	M	..	All metered			....	....	.....	.....	.35	.04½
No. Adams, Mass.	21 740[1]	M	..	6.00	3.00	3.00	6.00	....	3.00	21.00	.15	.10
Northampton, Mass.	20 220[1]	M	..	6.00	2.00	2.00	....	....	3.00	13.00	.10	.06
† Pittsfield, Mass.	32 121	M	..	5.00	2.50	3.75	....	....	6.25	17.50	.16	.12
Salem, Mass.	43 697	M	..	.....	....	....	....	....	.....	.....	.20	.06⅔
Somerville, Mass.	77 236	M	..	.....	13.00	....	....	....	4.00	17.00	.16	.16
Springfield, Mass.	88 926	M	..	8.00	4.00	4.00	....	....	5.00	21.00	.30	.07
Taunton, Mass.	34 259	M	..	5.00	3.00	5.00	2.00	....	5.00	20.00	.25	.09
Waltham, Mass.	27 834	M	..	6.00	2.00	3.00	1.00	1.00	6.00	19.00	.29½	.17½
Worcester, Mass.	145 986	M	..	6.00	4.00	5.00	1.50	1.50	5.00	23.00	.25	.10
Battle Creek, Mich.	25 267	M	..	6.00	2.00	3.00	....	....	4.00	15.00	.13	.06
Bay City, Mich.	45 166	M	..	6.00	2.00	2.00	1.00	1.00	3.00	15.00	.10	.05
Detroit, Mich.	465 766	M	..	3.20	1.00	1.60	.48	....	1.40	7.68	.05	.03
Grand Rapids, Mich.	112 571	M	..	4.00	2.00	4.00	2.00	2.00	3.00	17.00	.06	.06⅔
Jackson, Mich.	31 433	M	..	4.00	2.00	2.00	1.00	1.00	3.00	13.00	.13	.06⅔
Kalamazoo, Mich.	39 437	M	..	All metered			....	....	.....	.....	.13	.13⅓
Lansing, Mich.	31 229	M	..	4.00	2.50	2.50	....	....	2.00	11.00	.40	.05
Port Huron, Mich.	20 464[1]	M	..	4.50	2.00	2.00	1.00	....	6.00	15.50	.10	.06
Saginaw, Mich.	50 510	M	..	6.00	2.00	3.00	....	....	3.00	14.00	.11	.04
Duluth, Minn.	78 466	M	..	6.50	2.00	2.00	2.00	....	4.00	16.50	.23½	.06⅔
Minneapolis, Minn.	301 408	M	..	2.00	3.00	2.50	....	....	3.00	10.50	.08	.08
St. Paul, Minn.	214 744	M	..	3.80	2.00	2.00	....	....	3.00	10.80	.13⅓	.06⅔
Kansas City, Mo.	248 381	M	..	5.05	3.90	3.70	....	....	6.00	18.65	.25	.07
St. Joseph, Mo.	118 004[1]	..	P	4.50	3.00	3.00	....	....	4.00	14.50	.30	.06
St. Louis, Mo.	687 029	M	..	4.00	2.00	3.00	....	....	2.00	11.00	.25	.08
Springfield, Mo.	35 201	..	P	8.00	3.50	2.00	....	....	5.00	18.50	.25	.10
Butte, Mont.	39 165	..	P	18.00	6.00	....	....	....	12.00	36.00	.50	.20
Helena, Mont.	16 770[1]	..	P	12.00	4.00	4.00	3.00	....	7.50	30.50	.40	.20
Lincoln, Neb.	43 973	M	..	All metered			....	....	.....	.....	.15	.10
Omaha, Neb.	124 096	..	P	6.75	3.50	2.50	1.00	1.00	5.00	19.75	.35	.10
So. Omaha, Neb.	26 259	..	P	6.75	3.50	2.50	1.00	1.00	5.00	19.75	.35	.05
Concord, N. H.	21 210[1]	M	..	5.00	3.00	3.00	.50	....	3.00	14.50	.22½	.06⅔
Manchester, N. H.	70 063	M	..	4.50	2.00	2.50	.75	.75	3.50	14.00	.16⅔	.10⅔
Nashua, N. H.	26 005	..	P	6.00	2.00	4.00	....	....	4.00	16.00	.20	.05

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.—*Continued.*

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rates per 1 000 Gallons.	
		Municipal.	Private.	House Use, 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
Atlantic City, N. J.	44 461	M	..	$6.25	$2.75	$2.00	$1.75	....	$7.00	$19.75	$0.12	$0.12
Bayonne, N. J.	55 545	M	..	All metered			....	....	.....	.....	...	....
Camden, N. J.	94 538	M	..	5.00	3.00	3.00	1.00	$1.00	3.00	16.00	.20	.10
Hoboken, N. J.	70 324	M	..	10.65	2.70	1.80	....	....	2.70	17.85	.18	.11⅓
Jersey City, N. J.	267 779	M	..	12.55	4.00	3.00	....	....	5.00	24.55	.20	.10
New Brunswick, N. J.	23 758 [1]	M	..	6.00	4.00	5.00	1.00	2.00	5.00	23.00	.13½	.13½
Orange, N. J.	29 630	M	..	5.00	5.00	3.00	2.00	1.00	5.00	21.00	.25	.25
‖ Passaic, N. J.	54 773	..	P	All metered			....	....	.....	.....	.30	.10
Paterson, N. J.	125 600	..	P	12.00	....	....	....	....	6.40	18.40	.30	.10
Perth Amboy, N. J.	32 121	..	..	6.00	4.00	3.00	....	....	4.00	17.00	.25	.07
Plainfield, N. J.	19 088 [1]	..	P	6.00	4.00	5.00	2.00	3.00	5.00	25.00	.25	.15
§ Trenton, N. J.	96 815	M	..	4.50	2.25	2.25	.75	.75	2.25	12.75	.08	.08
W. Hoboken, N. J.	35 403	..	P	.....	....	....	....	....	.....	.....	.23⅓	.15½
Albany, N. Y.	100 253	M	..	12.00	....	....	....	....	5.00	17.00	.08	.08
§ Amsterdam, N. Y.	31 267	M	..	6.00	2.00	2.50	1.00	....	2.50	14.00	.22½	.04½
Auburn, N. Y	34 668	M	..	5.40	2.70	2.70	.90	1.80	3.60	17.10	.33⅓	.04⅓
Binghamton, N. Y.	48 443	M	..	3.00	3.00	3.00	1.00	2.00	3.00	15.00	.12	.06
Buffalo, N. Y.	423 715	M	..	4.50	1.00	1.50	....	....	.....	7.00	.06	.02
Elmira, N. Y.	37 176	..	P	6.00	4.00	4.00	2.00	....	3.00	19.00	.50	.10
Gloversville, N. Y	.....	M	..	.....	....	....	....	....	.....	.....	.16	.03½
Jamestown, N. Y.	31 297	M	..	5.00	2.50	2.50	....	....	6.00	16.00	.26⅔	.06⅔
Kingston, N. Y.	25 908	M	..	5.00	4.00	3.00	1.50	....	5.00	18.50	.22	.06⅔
Mt. Vernon, N. Y.	30 919	..	..	.....	....	....	....	....	.....	.....	.30	...
New York City, N. Y.	4 766 883	M	..	.....	....	....	....	....	.....	.....	.14	.14
Niagara Falls, N. Y.	30 445	..	..	5.00	3.00	3.00	1.00	....	5.00	17.00	.12	.03
Oswego, N. Y.	.....	..	..	.....	....	....	....	....	.....	.....	.25	.10
Poughkeepsie, N. Y.	27 936	M	..	3.50	1.50	2.00	.75	1.50	7.50	16.75	.16⅔	.04
Rochester, N. Y.	218 149	M	..	All metered			....	....	.....	.....	.14	.10
Schenectady, N. Y.	72 826	M	..	4.00	1.50	1.50	....	....	2.00	9.00	.32½	.09
Syracuse, N. Y.	137 249	M	..	.....	....	....	....	....	.....	.....	.18¾	.04 7/01

Troy, N. Y.	76 813	M	..	5.00	2.00	3.00	....	....	10.00	20.00	.05	.05
Utica, N. Y.	74 419	..	..	.....	....	....	....	....	.....	.....	.30	.06
Yonkers, N. Y.	79 803	M	..	All metered			....	....	.....	.....	.20	.20
Charlotte, N. C.	34 014	M	..	All metered			....	....	.....	.....	.25	.07
Wilmington, N. C.	25 748	..	P	All metered			....	....	.....	.....	.26	.08
Akron, Ohio	69 067	..	P	5.63	2.50	2.50	....	....	.....	10.63	.16	.08
Canton, Ohio	50 217	M	..	.....	....	....	....	....	.....	7.20	.07	.06
Cincinnati, Ohio	364 463	M	..	4.30	2.50	1.50	....	1.00	4.14	13.44	.10	.10
Cleveland, Ohio	560 663	M	..	.....	....	....	....	....	.....	.....	.05¼	.05½
Columbus, Ohio	181 548	M	..	6.00	4.00	4.00	2.50	....	5.70	22.20	.16	.12
Dayton, Ohio	116 577	M	..	4.00	2.00	2.50	1.00	2.00	3.30	14.80	.08	.06
Hamilton, Ohio	35 279	M	..	All metered			....	....	.....	.....	.16	.06
Lima, Ohio	30 508	M	..	6.00	3.50	2.50	....	....	6.00	18.00	.20	.08
Loraine, Ohio	28 883	M	..	.....	....	....	....	....	.....	.....	.20	.07
Mansfield, Ohio	20 142 [1]	M	..	5.00	3.00	3.00	....	2.00	3.00	16.00	.20	.06
Newark, Ohio	25 404	M	..	.....	....	....	....	....	.....	.....	.20	.06
Portsmouth, Ohio	20 714 [1]	M	..	6.00	3.00	3.00	1.00	....	.....	13.00	.25	.09
Springfield, Ohio	46 921	M	..	4.00	2.50	2.50	2.00	....	5.00	16.00	.10	.06
Toledo, Ohio	168 497	M	..	5.00	3.00	3.00	1.00	1.00	4.00	17.00	.10	.03½
Youngstown, Ohio	79 066	M	..	5.28	2.64	2.64	....	....	3.96	14.52	.20	.08
Zanesville, Ohio	28 026	M	..	5.30	1.00	3.00	2.50	....	4.50	16.30	.06	.06
Oklahoma, Okla.	64 205	M	..	6.00	5.00	3.00	1.00	....	6.00	21.00	.30	.20
Portland, Ore.	109 882 [1]	M	..	6.00	3.00	3.00	....	....	4.00	16.00	.16⅔	.16⅔
Easton, Pa.	28 523	..	P	10.00	3.00	4.00	1.00	....	3.00	21.00	.40	.08
Altoona, Pa.	52 127	M	..	4.80	3.00	2.00	.50	.50	.....	10.30	.33	.04
Allentown, Pa.	51 913	M	..	7.50	2.50	2.50	1.00	1.00	4.00	18.50	.12	.06
Chester, Pa.	38 537	M	..	.....	....	....	....	....	.....	.....	.30	.04
Erie, Pa	66 525	M	..	4.00	3.00	3.00	1.00	2.00	3.00	16.00	.20	.04
Harrisburg, Pa.	64 186	M	..	All metered			....	....	.....	.....	.16⅔	.02½
Johnstown, Pa.	55 482	..	P	9.75	3.00	3.00	1.00	1.00	5.00	22.75	.27	.05
Lancaster, Pa.	47 227	M	..	6.00	3.00	3.00	1.00	....	5.00	18.00	.12½	....
Lebanon, Pa.	19 404 [1]	M	..	3.00	2.00	2.50	.50	1.00	4.00	13.00	.50	.04½
McKeesport, Pa.	42 694	..	P	8.00	7.50	7.50	4.50	....	8.00	35.50	.26⅔	.09½
Newcastle, Pa.	36 280	..	P	7.00	3.00	3.00	1.00	1.00	2.50	17.50	.16	.08
†Norristown, Pa.	27 875	..	..	7.00	3.00	3.00	1.00	1.00	5.00	20.00	.26⅔	.06⅔
Philadelphia, Pa.	1 549 008	M	..	5.00	4.00	4.00	2.50	2.50	5.00	23.00	.04	.04
Pittsburg, Pa.	533 905	M	..	5.25	1.00	3.00	.75	.50	10.00	20.50	.18	.10
Reading, Pa.	96 071	M	..	4.50	2.50	2.00	1.00	....	8.00	18.00	.40	.03
Scranton, Pa.	129 867	..	P	6.00	4.00	4.00	2.00	....	8.00	24.00	.25	.06
Shamokin, Pa.	20 482 [1]	..	P	7.00	3.00	3.00	....	3.00	.....	16.00	.26⅔	.05⅓
Wilkesbarre, Pa.	67 105	..	P	.....	....	....	....	....	.....	.....	...	....
Williamsport, Pa.	31 860	..	P	6.00	5.00	5.00	1.00	....	6.00	23.00	.10	.05

TABULATION OF WATER RATES OF VARIOUS CITIES OF THE UNITED STATES, REVISED TO NOVEMBER, 1910.—*Continued.*

City.	Population, 1910.	Water Works.		Schedule of Water Rates.							Meter Rate per 1 000 Gallons	
		Municipal.	Private.	House Use 6 Rooms.	Bath.	Closet.	Additional Wash Stands.	Laundry Tubs.	Sprinkling 40 Feet with Privilege of Sprinkling Roadway.	Total.	Maximum.	Minimum.
York, Pa.	44 750	..	P	$6.00	$4.00	$4.00	$1.00	$1.00	$5.00	$21.00	$0.30	$0.06½
Newport, R. I.	27 149	..	P	7.00	5.00	5.00	....	....	10.00	27.00	.40	.25
Pawtucket, R. I.	51 622	M	..	All metered			....	....	.....	.....	.30	.06
Providence, R. I.	224 326	M	..	6.00	5.00	5.00	2.00	3.00	5.00	26.00	.20	.20
Woonsocket, R. I.	38 125	M	..	All metered			....	....	.....	.....	.30	.10
Columbia, S. C.	26 319	M	..	All metered			....	....	.....	.....	.15	.06¼
Charleston, S. C.	58 833	..	P	10.00	4.00	2.00	1.00	3.00	3.00	23.00	.25	.04½
Chattanooga, Tenn.	44 604	..	P	7.50	6.00	6.00	....	....	6.00	25.50	.25	.08
Knoxville, Tenn.	36 346	..	P	6.40	4.00	4.00	....	....	10.00	24.40	.18	.05
Memphis, Tenn.	131 105	M	..	6.00	5.00	5.00	....	....	10.00	26.00	.24	.10
Nashville, Tenn.	110 364	M	..	9.00	4.00	5.00	....	....	6.00	24.00	.20	.08
Austin, Tex.	29 860	M	..	All metered			....	....	.....	.....	.33	.07
Dallas, Tex.	92 104	M	..	8.00	6.00	4.00	....	....	2.50	20.50	.25	.12½
El Paso, Tex.	39 279	..	P	All metered			....	....	.....	.....	.20	.12½
Ft. Worth, Tex.	73 312	M	..	....	....	....	....	....	.....	.....	.30	.30
Galveston, Tex.	36 981	M	..	6.00	6.00	3.00	3.00	2.00	4.00	24.00	....	....
Houston, Tex.	78 800	M	..	12.00	3.00	6.00	3.00	....	.....	24.00	.50	.20
Waco, Tex.	26 425	M	..	7.00	5.00	3.00	....	....	7.20	22.20	.40	.15
Ogden City, Utah	17 165[1]	..	P	6.50	1.00	1.50	....	....	.....	.....	.20	.06
Salt Lake City, Utah	92 777	M	..	4.50	1.00	2.00	....	....	6.00	13.50	.10	.03½
Lynchburg, Va.	29 494	M	..	6.00	3.00	3.00	2.00	....	3.00	17.00	.20	.03
Newport News, Va.	28 749[1]	..	P	10.00	3.50	3.50	....	....	.....	17.00	.30	.10½
Norfolk, Va.	67 452	M	..	5.60	2.40	2.40	....	....	2.40	12.80	.09	.09
Petersburg, Va.	21 810[1]	M	..	All metered			....	....	.....	.....	.20	.07
Richmond, Va.	127 628	M	..	4.00	3.50	3.00	....	....	8.80	19.30	.15	.05
Roanoke, Va.	34 874	..	P	9.00	3.00	3.00	1.50	3.00	3.00	22.50	.25	.10
Seattle, Wash.	.....	M	..	7.80	2.40	2.40	....	....	.....	.....	.26	.05¼
Spokane, Wash.	47 006[1]	M	..	12.00	2.40	2.40	....	....	2.00	18.80	.15	.15
Tacoma, Wash.	82 972	M	..	11.40	2.40	2.40	....	....	4.80	21.00	.40	.11

Charleston, W. Va.	.....	..	..	....	....	....	....	....	.....	.....	.25	.07½
Wheeling, W. Va.	41 641	M	..	6.00	1.50	6.00	....	....	6.00	19.50	.15	.15
Eau Claire, Wis.	18 981[1]	..	P	6.80	4.00	4.00	2.00	....	6.00	22.80	.30	.08
Green Bay, Wis.	25 236	..	P	6.00	4.00	4.00	2.00	....	6.00	22.00	.40	.20
La Crosse, Wis.	30 417	M	..	5.00	2.00	3.00	....	2.00	5.00	17.00	.20	.04
Madison, Wis.	25 531	M	..	.....	....	....	....	....	.....	.....	.18	.05
Milwaukee, Wis.	373 857	M	..	All metered				....	....	.....	.....	.06
Oshkosh, Wis.	33 062	..	P	6.00	2.00	4.00	1.00	....	5.00	18.00	.40	.05
Racine, Wis.	38 002	..	P	4.80	3.60	4.00	1.80	....	4.80	19.00	.30	.06
Superior, Wis.	37 643[1]	..	P	6.40	4.00	4.00	....	....	9.60	24.00	.40	.08

*10%. †20%. ‡Credit $1.50. §25%. ‖Less 5%." [1] Population 1906 estimate.

COMPARISON OF THE WATER RATES OF INDIANAPOLIS WITH THOSE OF CITIES OF THE UNITED STATES HAVING A POPULATION OF 20 000 OR OVER.

	For Family Use for House of 6 Rooms with Hot and Cold Water at Kitchen Sink.	For Family Use. Bath, Water Closet, Wash Stands, Sinks, etc., Complete for House of 6 Rooms.	For Family Use. Bath, Water Closet, Wash Stands, etc., Complete for House of 6 Rooms; also Sprinkling for Lot of 40-Foot Frontage with Privilege of Sprinkling Roadway.	METER RATES.	
				Maximum per 1 000 Gallons.	Minimum per 1 000 Gallons.
Rates in 237 cities where water is supplied by private company or municipal plant	$6.40	$14.09	$18.98	$0.22 3/10	$0.09
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 75 cities where water is supplied by private company	7.06	15.75	20.90	.30	.09⅔
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 32 cities having population more than 100 000	6.25	14.24	19.60	.18	.08⅓
Indianapolis rate	5.00	11.00	17.00	.18	.04½
Rates in 162 cities where water is being supplied by municipal plant	6.05	13.34	17.80	.20	.09
Indianapolis rate	5.00	11.00	17.00	.18	.04½

TABLE SHOWING PERCENTAGE OF PIPE OF VARIOUS SIZES IN CITIES OF THE UNITED STATES. — (*Compiled 1908.*)

CITY.	Population according to Gov't Estimate of 1906.	Mileage of Mains Last Report in Our Files.	Percentage of 3-Inch and 4-Inch Pipe in System.	Percentage of 6-Inch Pipe in System.	Percentage of 8-Inch Pipe in System.	Percentage of 10-Inch Pipe in System.	Percentage of Pipe 12-Inch or Larger.
Atlanta, Ga.	104 984	163	5	69	6	5	15
Atlantic City, N. J.	39 544	79	26	21	17	3	33
Baltimore, Md.	553 669	664	40	28	2	12	18
Boston, Mass.	602 278	735	2	34	16	4	44
Buffalo, N. Y.	381 819	504	7	58	1	8	26
Chicago, Ill.	2 049 185	2 073	8	54	22	..	16
Cincinnati, Ohio	345 230	490	30	38	6	13	13
Cleveland, Ohio	460 327	605	6	55	15	7	17
Columbus, Ohio	145 414	210	11	57	17	1	14
Denver, Colo.	151 920	379	17	47	10	4	22
Detroit, Mich.	353 535	709	24	49	11	6	10
Erie, Pa.	59 993	122	27	55	2	..	16
Evansville, Ind.	63 957	77	17	60	8	2	13
Grand Rapids, Mich.	99 794	166	24	39	13	5	19
Jersey City, N. J.	237 952	225	4	60	12	2	22
Kansas City, Mo.	182 376	342	9	51	16	7	17
Louisville, Ky.	226 129	271	23	49	8	1	19
Memphis, Tenn.	125 018	156	16	48	8	7	21
Milwaukee, Wis.	317 903	409	..	73	14	..	13
Minneapolis, Minn.	273 825	331	..	57	17	1	25
Nashville, Tenn.	84 703	110	14	63	6	..	17
Newark, N. J.	289 634	278	10	67	3	4	16
New Bedford, Mass.	76 746	106	15	37	22	8	18
Newton, Mass.	37 475	141	9	56	21	1	13
Philadelphia, Pa.	1 441 735	1 500	3	68	4	6	19
Pittsburg, Pa.	375 082	370	17	50	10	2	21
Providence, R. I.	203 243	363	..	67	16	1	16
Reading, Pa.	91 141	110	12	44	3	12	29
Rochester, N. Y.	185 703	290	24	43	15	4	14
St. Louis, Mo.	649 320	813	2	59	1	1	37
St. Paul, Minn.	203 815	284	5	63	1	..	31
Springfield, Mass.	75 836	157	8	49	17	1	25
Toledo, Ohio	159 980	202	6	70	13	1	10
Washington, D. C.	307 716	437	9	65	5	..	21
Wilmington, Del.	85 140	119	31	19	32	1	17
Average	.....	...	13 per ct.	52 per ct.	11 per ct.	4 per ct.	20 per ct.
Indianapolis, Ind.	219 154	293	7 per ct.	48 per ct.	21 per ct.	5 per ct.	19 per ct.

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES OF THE UNITED STATES. — (*Compiled in 1908.*)

CITY.	Source of Supply.	System whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Adrian, Mich.	Wolf Creek	Reservoir	80 to 100	None	$50.00	...	Metered	None
Akron, Ohio	Wells	Direct	No	80 per cent.	40.00	400	Metered	15 per ct.
Albany, Ind.	Wells	Direct	100	None	.....	821	.....	.....
Anniston, Ala.	Springs	Reservoir	No	None	50.00	500	.....	Very small
Ann Arbor, Mich.	Wells	Reservoir	No	None	45.00 & 40.00	700	Yes	Not any
Ashland, Wis.	Lake Superior	Direct	120	None	61.62	528	.....	Ab't 8 p. c.
Alton, Ill.	Mississippi River	Standpipe	.....	None	40.00	500	.....	.....
Atchison, Kan.	Missouri River	Reservoir	None	All fires	40.00	...	None	10 per ct.
Baton Rouge, La.	Deep wells	Reservoir	90 to 100	None	50.00	440	.....	None
Belleville, Ill.	Wells	Direct	75 to 100	None	75.00–60.00	450	Yes	1 per ct.
Beloit, Wis.	Springs	Direct	80 to 100	None	60.60–40.00	500	Metered	5 per ct.
Birmingham, Ala.	River	Reserv'r & direct	None	All fires	55.00	1 000	Metered	.....
Brainard, Minn.	Mississippi River	Direct	80 to 120	None	66.10	700	No	5 per ct.
Bridgeport, Conn.	Small streams	Reservoir	None	All fires	12.50	...	Metered	2 per ct.
Bristol, Conn.	Small streams	Reservoir	None	None	20.00	...	.....	Less than 1
Bucyrus, Ohio	.....	Direct	80	None	40.00	600	Some	1 per ct.
Burlington, Ia.	Mississippi River	Direct	120 to 145	None	45.00	...	No	5 per ct.
Butte, Mont.	Mountain streams	Reservoir	None	None	50.00	...	No	.....
Charleston, S. C.	Creek	Direct	None	All fires	.....	500	.....	10 per ct.
Charleston, W. Va.	Elk River	Direct	100	None	50.00	300	No	.....
Chester, Pa.	Delaware River	Reservoir	None	None	40.00	1 000	Yes, al]	None
Chillicothe, Mo.	Wells and river	Direct	65	None	39.50	...	No	1 per ct.
Clinton, Mo.	Deep wells	Reservoir	150	None	.....	600	.....	.....
Clinton, Ia.	Artesian wells	Direct	100 to 120	None	30.00	450	No	.....
Columbia, Pa.	Susquehanna Riv'r	Reservoir	None	All fires	City hydrant	...	.....	.....
Columbus, Ga.	Springs	Standpipe	None	None	80.00–40.00	600	.....	5 per ct.
Cortland, N. Y.	Springs	Standpipe	No	5 per cent.	33.33	500	.....	Very little
Council Bluffs, Ia.	Missouri River	Reservoir	140	None	60.00	650	Yes	.....
Creston, Ia.	Reservoir	Standpipe	80 to 140	50 per cent.	50.00	400	Metered	.....
Danville, Ill.	Vermilion River	Direct	100 to 125	None	40.00	500	No	.....
Davenport, Ia.	Mississippi River	Direct	65 to 125	None	38.00	450	Metered	None
Defiance, Ohio	River	Standpipe	No	None	40.00–35.00	500	No	.....
Denison, Tex.	.....	Standpipe	125	.....	79.25	...	.....	.....
Denver, Colo.	Platte River	Gravity & pumps	No	All fires	25.00–35.00	400	Metered	6 per ct.
Des Moines, Ia.	Underground gal.	Direct	140	None	.....	...	No	33 per ct.
Durham, N. C.	Rivers	Reservoir	90 to 120	None	50.00–40.00	500	No	.....

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES OF THE UNITED STATES.
(Compiled in 1908.) — Continued.

CITY.	Source of Supply.	System whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Easton, Pa.	Delaware River	Reservoir	No	.....	.....	...	Metered	.....
E. Providence, R. I.	Ten Mile River	Direct & st'ndpipe	130 to 150	None	$20.00	...	Metered	.....
Eau Claire, Wis.	Wells	Direct	140	.....	54.00–44.00	528	No	5 per ct.
Elkhart, Ind.	Deep wells	Direct	80 to 115	All fires	59.00	500	No	15 per ct.
Elmira, N. Y.	River	Reservoir	No	All fires	.....	...	.....	.....
El Paso, Tex.	Wells	Direct	No	.....	52.00	700	Metered	$1\frac{3}{5}$ per ct.
Elwood, Ind.	Driven wells	Direct	100	None	60.00	528	No	$\frac{1}{2}$ per ct.
Eureka, Cal.	Elk River	Standpipe	100	All fires	37.50	612	Metered	$\frac{1}{2}$ per ct.
Freeport, Ill.	Wells	Standpipe	80 to 100	None	50.00	528	No	15 per ct.
Fort Madison, Ia.	Mississippi River	Reserv'r & direct	125 to 140	None	40.00	380	Metered	$\frac{1}{4}$ per ct.
Franklin, Ind.	Driven wells	Standpipe	60	None	40.00	528	No	2 per ct.
Gadsden, Okla.	River	Reservoir	No	All fires	46.16	528	No	.....
Green Bay, Wis.	Wells	Reservoir	100	None	37.50	500	No	.....
Greensburg, Ind.	Driven wells	Direct	100	None	33.00	500	No	.....
Greenville, S. C.	Mountain streams	Reservoir	No	None	40.00–30.00	400	Metered	.....
Greenwich, Conn.	Reservoir	Gravity system	No	5 per cent.	25.00	...	Metered	.....
Hagerstown, Md.	Mountain reserv'r	Reservoir	.....	None	45.00	500	No	None
Hopkinsville, Ky.	Creeks	Standpipe	No	None	40.00–30.00	500	.....	5 per ct.
Huntington, W. Va.	Ohio River	Reservoir	No	None	40.00	528	No	.....
Iowa City, Ia.	Iowa River	Direct	125	None	45.00–50.00	400	.....	5 per ct.
Iron Mount, Mich.	Wells	Reservoir	60–135	None	58.00	500	Metered	5 per ct.
Iron Wood, Mich.	Montreal River	Standpipe	Yes	None	75.00–50.00	450	No	Not large
Johnstown, Pa.	Mountain springs	Gravity system	No	.....	25.00	...	Some	1 per ct.
Joplin, Mo.	Creek	Direct	Yes. 80–100	.....	22.50	...	No	.....
Kankakee, Ill.	Kankakee River	Direct	100	None	.....	...	.....	1 per ct.
Keokuk, Ia.	Mississippi River	Direct	140	None	50.00	732	No	1 per ct.
Knoxville, Tenn.	Tennessee River	Res. & standpipe	90 to 100	15 per cent.	40.00–45.00	600	Partly	Less th'n10
Kokomo, Ind.	Well	Direct	100	None	25.00	500	No	2 per ct.
Leavenworth, Kan.	Missouri River	Direct and res'rv'r.	No	None	40.00	...	No	.....
Lexington, Ky.	Reservoir	Direct	100	None	50.00	300	No	$1\frac{1}{2}$ per ct.
Lincoln, Ill.	Wells	St'dpipe & direct	110	None	35.00	528	No	8 per ct.
Linton, Ind.	Wells	Direct	No	None	50.00	...	No	Very little
Little Rock, Ark.	Arkansas River	Gravity	No	All fires	50.00	528	No	10 per ct.
Long Branch, N. J.	Surface streams	Direct	70 to 80	Partly	25.00	...	Yes	None
Louisiana, Mo.	Mississippi River	Reservoir	No	None	50.00–33.00	300	No	.....
Macon, Ga.	River	Gravity	No	All fires	40.00–37.50	500	Metered	None

Manitowoc, Wis.	Wells	St'dpipe & direct	100 to 120	.....	65.00–40.00	528	No	.....
Mexico, Mo.	Surface	Direct	100	None	55.00–50.00	600	No	.....
Michigan City, Ind.	Lake Michigan	Direct	100	5 per cent.	.....	400	No	$\frac{1}{16}$ per ct.
Milford, Mass.	Wells and lake	Direct	110	50 per cent.	50.00	300	Yes	None
Moberly, Mo	Dammed creek	Direct	120	None	84.00	500	No	11 per ct.
Mt. Vernon, Ind.	Ohio River	Direct & reservoir	87	.....	37.50	500	No	$\frac{1}{4}$ per ct.
Nashua, N. H.	Springs and wells	Reserv'r and direct	100	90 per cent.	30.00	...	Metered	None
New Albany, Ind.	Ohio River	Reservoir	No	None	60.00–50.00	...	Metered	.....
Newark, Ohio	River	Reservoir	No	None	48.00–45.00	400	No	.....
New Haven, Conn.	Lakes and rivers	.....	No	All fires	.....	...	No	.....
New Orleans, La.	Mississippi River	Direct	No	All fires	60.00–45.00	...	.....	.....
Newport News, Va.	Streams	Standpipe	.....	Less than 50	25.00	...	Metered	.....
Newport, R. I.	Brooks	Reservoir	No	All fires	35.00	...	Yes	No data
Noblesville, Ind.	Deep wells	Reservoir	80 to 120	None	33.33	528	No	5 per ct.
Norristown, Pa.	Schuylkill River	Reservoir	No	50 per cent.	.....	...	No	.....
Norwich, Conn.	.....	Reservoir	No	75 per cent.	40.00–15.00	...	No	.....
Oconta, Wis.	Wells	Reservoir	100	None	65.00–50.00	400	No	.....
Ogden, Utah	Ogden River	Reservoir	120	None	35.00	...	No	10 per ct.
Omaha, Neb.	Missouri River	Direct & reservoir	No	None	60.00	400	Some	12 per ct.
Oneonta, N. Y.	Springs	Reservoir	No	10 per cent.	25.00	...	No	.....
Oshkosh, Wis.	Lake Winnebago	Direct	90 to 125	None	40.00–25.00	528	No	.....
Oskaloosa, Ia.	Rivers and wells	Direct & st'dpipe	135	None	50.00	645	No	37 per ct.
Owensboro, Ky.	Ohio River	Direct	80 to 120	None	50.00–40.00	300	Yes	.....
Ottumwa, Ia.	Des Moines River	Reservoir	No	None	42.00	400	No	5 per ct.
Paducah, Ky.	Ohio River	Standpipe	110	1 per cent.	28.50	400	No	5 per ct.
Paterson, N. J.	Passaic River	Direct & st'dpipe	No	All fires	30.00	400	Metered	.....
Pensacola, Fla.	Driven wells	Standpipe	Yes	None	60.00–40.00	528	.....	.....
Peoria, Ill.	Wells	Reserv'r & direct	No	50 per cent.	41.60–25.00	440	No	15 per ct.
Pine Bluffs, Ark.	Deep wells	Direct	100	None	43.00–40.00	500	No	1 per ct.
Pittsburg, Kan.	Wells	Tank	110	None	46.00–45.00	500	No	6 per ct.
Plainfield, N. J.	Driven wells	Standpipe	No	None	15.00	...	Yes	.....
Portland, Me.	Sebago Lake	Gravity	.....	All fires	City hydrant	...	.....	.....
Quincy, Ill.	Mississippi River	Reservoir	No	All fires	45.00–20.00	...	Some	2 per ct.
Raleigh, N. C.	Creek	Standpipe & direct	100	None	32.50	528	No	$12\frac{1}{2}$ per ct.
Rensselaer, N. Y.	Hudson River	Standpipe	125	None	40.00	500	Some	.....
Richmond, Ind.	Galleries	Reservoir	110	None	55.00–49.00	500	No	5 per ct.
Roanoke, Va.	Springs	Direct	No	10 per cent.	20.00	...	Metered	None
St. Joseph, Mo.	Missouri River	Reservoir	No	None	40.00	500	No	3 per ct.
San Antonio, Tex.	Wells	Reservoir & direct	90	25 per cent.	.....	...	Yes	$33\frac{1}{3}$ per ct.
San Francisco, Cal.	Mt. str'ms & lakes	Reservoir	No	All fires	.....	City hydrants	.....	.....
San Jose, Cal.	Mountain streams	Direct	No	All fires	6.00	City hydrants	Yes	.....
Sedalia, Mo.	River & reservoir	Direct	100	None	30.00	528	Yes	$\frac{1}{4}$ per ct.

DATA REGARDING FIRE HYDRANT SERVICE IN VARIOUS CITIES OF THE UNITED STATES.
(Compiled in 1908.) — Continued.

CITY.	Source of Supply.	System, whether Direct, Reservoir, or Standpipe.	Is Pressure Raised; if so, What Pressure?	At What Per Cent. of Fires is Steamer Used?	Amount Hydrant Rental.	No. of Feet of Pipe Required for Each Hyd't.	Do You Receive Revenue for City Bld'gs, Parks, Etc.?	Per Cent. of Total Pumpage.
Seymour, Ind.	White River	Standpipe	100	None	$45.00–$35.00	350	No	2 per ct.
Shamokin, Pa.	Gravity	.....	.....	None	City hydrant	...	.....	.....
Sharon, Pa.	Shenango River	Direct	140	None	35.00	...	No	5 per ct.
Shelbyville, Ind.	Wells	Direct	100	None	30.00	528	No	.....
Shreveport, La.	River	Direct	No	All fires	50.00–40.00	...	No	.....
S. Bethlehem, Pa.	Lehigh River	Reservoir	No	None	25.00	...	Yes	.....
Southbridge, Mass.	Hatchet p. & brook	Gravity	No	None	30.00	500	Yes	.....
Springfield, Mo.	Springs	Standpipe	No	50 per cent.	40.00	600	No	2 per ct.
Stockton, Cal.	Wells	Direct	No	75 per cent.	12.00	...	Metered	None
Streeter, Ill.	River	Direct	100	.....	45.00–35.00	590	No	14 per ct.
Sunbury, Pa.	Lit. Shamokin cr.	Direct	100	.....	18.00	...	No	None
Superior, Wis.	Wells	Direct	120	Small per ct.	40.00	528	No	.....
Tampa, Fla.	Wells	Standpipe	110	All fires	35.00	400	Metered	None
Texarkana, Ark.	Wells	Direct	80	30 per cent.	30.00	400	Metered	2 per ct.
Uhrichsville, Ohio	Creek	Reservoir	No	None	40.00	500	No	.....
Valparaiso, Ind.	Flint Lake	Direct	90	None	50.00	500	Yes	.....
Vincennes, Ind.	Wabash River	Standpipe	No	None	33.33–40.00	450	No	.....
Wabash, Ind.	Wells	St'dpipe & direct	130	None	38.00	528	Metered	.....
Warren, Ohio	Mahoning River	Standpipe	120	None	45.00–25.00	528	.....	.....
Washington, Ind.	White River	Standpipe	120	None	35.00	...	No	6 per ct.
Washington, Pa.	Impounding dams	Reservoir	No	None	40.00	...	Metered	None
Waterloo, Ia.	Deep wells	Direct & st'pipe	100	None	35.00	400	.....	.....
Williamsport, Pa.	Mountain streams	Direct	No	10 per cent.	City hydrant	City hydrants	Yes	.....
Wilmington, N. C.	River	Standpipe	120	5 per cent.	50.00	...	Yes	15 per ct.
Winchester, Ky.	Impounding res.	Direct & st'pipe	115	None	40.00	400	Yes	.....
Winfield, Kan.	Walnut River	Reservoir	No	None	57.00	600	No	1 per ct.
York, Pa.	Surface streams	.....	No	All fires	.....	City hydrants	No	5 per ct.
Indianapolis, Ind.	**Wells and filter plant**	**Direct**	**120**	**5 per cent.**	**45.00**	**500**	**Practically nothing**	**10 per ct.**

NUMBER OF FEET OF PIPE TO EACH FIRE HYDRANT IN VARIOUS CITIES OF THE UNITED STATES.

(*Compiled in 1908.*)

CITY.	Population According to Gov't Estimate of 1906.	Mileage of Mains.	Number of Fire Hydrants.	Number of Feet of Pipe to Fire Hydrants.
Denver, Colo.	151 920	500	3·200	790
Wilmington, Del.	85 140	119	882	710
Atlanta, Ga.	104 984	180	1 668	570
Augusta, Ga.	43 125	60	750	420
Savannah, Ga.	68 596	67	663	540
Aurora, Ill.	26 823	59	499	620
Chicago, Ill.	2 049 185	2 073	21 183	516
Decatur, Ill.	24 727	45	465	511
Peoria, Ill.	66 365	100	1 200	440
Terre Haute, Ind.	52 805	70	928	398
Burlington, Ia.	25 741	32	335	505
Davenport, Ia.	40 706	75	668	590
Des Moines, Ia.	78 323	130	1 400	490
Kansas City, Kan.	77 912	58	464	660
Paducah, Ky.	30 329	36	424	448
Orange, N. J.	26 493	40	400	528
Paterson, N. J.	112 801	125	1 337	493
Auburn, N. Y.	32 963	70	600	616
Binghamton, N. Y.	43 785	80	800	566
Buffalo, N. Y.	381 819	516	4 891	557
Gloversville, N. Y.	18 624	33	289	603
Rochester, N. Y.	185 703	325	3 500	490
Schenectady, N. Y.	61 919	176	2 769	299
Troy, N. Y.	76 513	104	1 024	536
Yonkers, N. Y.	64 110	103	1 111	490
Cleveland, Ohio	460 327	676	7 966	448
Columbus, Ohio	145 414	210	1 740	630
Dayton, Ohio	100 799	152	1 527	525
Hamilton, Ohio	27 670	43	425	534
Toledo, Ohio	159 980	215	1 650	688
Allegheny, Pa.	145 240	200	1 789	590
Philadelphia, Pa.	1 441 735	1 500	14 311	552
Pittsburg, Pa.	375 082	402	3 753	565
Reading, Pa.	91 141	109	909	633
Boston, Mass.	602 278	743	7 772	505
Fall River, Mass.	105 942	101	1 153	462
Cambridge, Mass.	98 544	128	1 046	646
Holyoke, Mass.	50 778	82	659	657
Lowell, Mass.	95 173	140	1 271	581
Lynn, Mass.	78 743	138	825	883
New Bedford, Mass.	76 746	106	1 105	508
Somerville, Mass.	70 798	91	1 018	472
Springfield, Mass.	75 836	156	1 174	701

NUMBER OF FEET OF PIPE TO EACH FIRE HYDRANT.—*Continued.*

CITY.	Population According to Gov't Estimate of 1906.	Mileage of Mains.	Number of Fire Hydrants.	Number of Feet of Pipe to Fire Hydrants.
Taunton, Mass.	30 953	82	877	494
Detroit, Mich.	353 535	709	4 752	790
Grand Rapids, Mich.	99 794	165	1 547	563
Jackson, Mich.	25 360	72	600	633
Minneapolis, Minn.	273 825	342	3 893	464
St. Paul, Minn.	203 815	285	2 658	566
Kansas City, Mo.	182 376	342	4 024	448
St. Joseph, Mo.	118 004	115	895	678
St. Louis, Mo.	649 320	813	9 298	462
Lincoln, Neb.	48 232	67	568	623
Omaha, Neb.	124 167	235	1 991	667
Atlantic City, N. J.	39 544	65	670	501
Jersey City, N. J.	237 952	224	2 331	508
Woonsocket, R. I.	32 994	53	624	441
Charleston, S. C.	56 317	59	605	510
Nashville, Tenn.	84 703	110	931	624
Dallas, Tex.	52 793	100	800	660
Galveston, Tex.	34 355	31	460	356
Ft. Worth, Tex.	27 096	85	876	510
Average	174 355	231	2 257	555
Indianapolis	219 154	293	2 294	674

DISCUSSION.

MR. LEONARD METCALF.* I want to say one word with regard to the third table. It was prepared at the time that negotiations were pending with the city for the making of a new hydrant rental contract. The statistics were obtained by correspondence, tabulations were made, and the data were subsequently submitted, by Mr. Jordan, if I remember rightly, to the men who had furnished the data. All of that correspondence was thrown open to the city officials and any interested parties, as well as to the officials of the water company. I glanced over more or less of it myself, and I have every confidence in its accuracy. I know that the results were accepted by the city as being thoroughly credible and easily subject to verification.

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

MR. W. C. HAWLEY.* This paper shows that for a considerable period of time in most of the cases the company was doing a losing business on the extensions of its distributing system, and it would be interesting to know on what basis these extensions were made. From the figures given it appears in some cases that for several years the revenue per mile was not sufficient to pay interest, depreciation, maintenance, and taxes on the cost of the extension alone, to say nothing of bringing in a revenue to cover the furnishing of water and the other operating and general expenses of the plant. The query is, How can a company reasonably be expected to do business on such a basis? In the case of a municipal plant, with the taxing power of the municipality behind it, extensions are generally made with very little attention to the revenue to be derived therefrom. In the case of a private corporation, it is very different. Such losses must either go to increase the ultimate going value of the concern, or else the rate or rates for water must be enough higher upon all the consumers who are supplied by the company to cover the losses on these extensions.

It might be interesting if we could get the views of various members and statements from various municipal as well as privately owned water works as to the requirements of each for making extensions to reach new consumers.† In the case of our company, we expect a return of at least 15 per cent. per year on the cost of making an extension. We figure that 15 per cent. barely covers interest, depreciation, maintenance, taxes, and the cost of furnishing the water, without leaving any profit. In cases where there are no consumers ready to take water, as, for instance, when some real estate project is being boomed, we ask the parties interested to advance the entire cost of making the extension. The company then lays the pipe and returns to those who have advanced the money the amount of which our minimum rate is 15 per cent. per year for each *bona fide* consumer who takes a supply of water. For the purpose of comparison of this method with the revenues stated in Mr. Jordan's paper, assume that an

* Chief Engineer, Pennsylvania Water Company, Williamsburg, Pa.

† At the November, 1909, meeting, a committee was appointed to report on the conditions under which extensions of water mains are made by town-owned water supplies. JOURNAL N. E. W. W. ASSOCIATION, Vol. XXIII, p. 450. — ED.

extension of a mile of pipe costs $5 000. Fifteen per cent. of this amount would be $750, and if the municipality is generous and orders the setting of five fire hydrants on this mile of pipe at, say, $40 per year each, or a total of $200 for fire protection, the domestic revenue thus required is $550. This, if we assume a minimum rate of $10 per year per tap, would require 55 taps, and on anything less than this, the company is doing a losing business.

MR. LEONARD METCALF. I want to echo what Mr. Hawley has said. It seems to me that he has touched upon a point which is entitled to very serious consideration in the operation of water works. It is undoubtedly a fact that many extensions laid by water companies or municipalities do not earn an adequate return for several years, that is, for many years after construction. That, of course, does lead to an increased going value of the plant, and it seems to me that that fact very effectually meets what I believe to be an error in the position of the Wisconsin Public Service Commission, on the interpretation of going value. It seems to me that under normal circumstances the going value of any plant must increase from year to year, and that the correct measure of going value is not the cost of advertising and the cost of acquisition of any business, in the sense which has been used by the Wisconsin commission.

Mr. Hawley's statement immediately brings one face to face with this question: What shall the policy of the city be with regard to its charge for franchise and the limitation of the conditions under which the public service corporation shall operate? Shall the city make the public service corporation a source of income, or provide such conditions that the public service corporation can render the largest measure of service at the smallest cost, and then by a suitable system of inspection see to it that the city shall get what it should from the company? Of course, if you make the conditions under which the company operates as easy as possible, the company can borrow money at a low rate of interest and, having correspondingly smaller charges to meet than if it were paying a heavy franchise tax, for instance, the service can be more readily extended to outlying districts of the city. That should be of advantage to the city. Under the other policy, the heavier the charges which the company has to meet, the greater

the burden, the less likely will it be to meet the growing needs of the city in the outlying districts. Of course I recognize the fact that in many cases companies may not have been as liberal as they should have been, and the city has felt that the only way in which it could retaliate was by increasing the burden on the company, or, rather, by getting an income from the company through a franchise tax or some similar means. I believe, however, that that is, after all, only a system of taxation, and while it may be a good one, as it can be more readily levied, more equitably levied, than some other systems of taxation, fundamentally it does not seem to me right. It seems to me that the best interests of the city are subserved when the conditions of operation are made as easy as possible, and when the service can be extended as rapidly as possible by the company.

MR. WILLIAM F. SULLIVAN.* There is one source of income that is of interest to many water-works managers of both municipal and privately owned plants, and that is the hydrant rental. Some municipally owned water works do not make any charges for hydrants, others only a nominal amount covering installation and other expenses. In private companies, whenever there is a renewal of a hydrant contract, it is generally brought before the public and they, without fully understanding the subject, question the price which to many water-works people seems a fair and just one. I had hoped that Mr. Jordan would be here in person, and give us some sidelights on the hydrant income question.

I would like to hear from some of the members present with reference to hydrant charges, whether they consider it fair and equitable for cities to pay nothing for hydrants, thus compelling the water takers to assume the expense of hydrant protection, or whether the municipality should not pay a fair sum for hydrants.

Mr. Tighe stated that the hydrant rental in Holyoke was eight dollars each per annum, and that such charge covered the total cost.

MR. JAMES L. TIGHE.† In the city of Holyoke the municipal water works not only maintains itself, but also pays a tax to the city, as if it were a private corporation. It does all this on an

* Superintendent Pennichuck Water Works, Nashua, N. H.
† Engineer Water Works, Holyoke, Mass.

income which is somewhat less than eight per cent. of the physical value or actual cost of the construction of the works.

In return for the payment of this tax, the water department collects from the municipality payment for all the water which the municipality uses at the same prices as are charged private consumers.

Many people argue that this tax that is placed upon the water department or water taker is an unjust one, but, so far as I can see, it is an eminently just and equitable one, because the water department has certain privileges from the municipality which it should be willing to pay something for. It has, for instance, a valuable franchise that permits it to tear up and lay pipes through the streets. It has also police protection for nothing, and, last but not least, it has the credit of the city behind it which enables it not only to borrow money, but to borrow it at a low rate of interest.

Now, are these privileges not worth something, and is it not just or equitable that the water taker should pay something for them?

Mr. Metcalf mentioned that $18.00 is a fair amount to charge for water per year per family. In Holyoke we charge for water the net sum of $6.66 per year per family. This does not include the lawn hose, which is $2.14 extra per year. It includes, however, all the modern fixtures and conveniences installed.

Holyoke is a very sanitary city, and, in order to encourage sanitation as much as possible, nothing is charged to families for duplicate fixtures such as bath-tubs, closets, faucets, or wash basins, no matter how many are installed.

Our water rates were cut down over thirteen thousand dollars last year, which makes the rates now in Holyoke about the lowest in any city in the country; that is, the lowest for a plant that maintains itself, or more especially for a plant that maintains itself and contributes between one fifth and one sixth of its income in taxes to the general taxation fund of the municipality.

In relation to metered water used for mechanical and manufacturing purposes, there is charged for this the net flat rate of 5.1 cents per 1 000 gallons, together with an annual charge for the meter of from 10 to 12 per cent. of its cost price. I do not think

that this price for metered water can be beaten very much anywhere.

There is also a metered rate for what is called tenement or apartment blocks containing four or more tenements. This metered rate was made especially for this class of property in order to discourage waste, and does not apply to residences because those living in the latter do not favor meters or want to be bothered with them, or with the meter men coming around once a month to read them, even though such would cut down the bills, and why should they so long as the schedule rates give them all the water they need, and especially all they can waste, for the small sum of $6.66 per year.

The minimum net rate for the tenement or apartment block is fixed at $4.50 per year per tenement. This amount has to be paid, together with the 10 or 12 per cent. interest on the first cost of the meter, no matter now little the quantity of water used. For this amount of $4.50, each family is allowed 88 000 gallons per year, which is almost 50 gallons per capita per day, assuming a family of five to each tenement. Should a larger quantity than 88 000 gallons per year — or 22 000 gallons per quarter — be used, it is charged for at the usual flat rate of 5.1 cents per 1 000 gallons.

This meter rate per tenement for the average tenement or apartment block, namely, an eight-tenement block, gives a minimum cost of $4.75, or a cost 29 per cent. less than the schedule rate per tenement.

In Holyoke, pipe lines are laid and extended in streets to accommodate all buildings, even if there be but one house on a street.

I was thinking, when Mr. Metcalf and Mr. Hawley were speaking in relation to pipe extensions in the outlying districts of a community, from which little returns could be expected for years, of asking the question as to what about the returns that are received from the thickly populated centers of the community. Should not these offset those from the outlying districts, or both go together?

The charge for hydrant service in Holyoke is $8.00 per hydrant, which includes all the water used for fire purposes. This charge is based only on the actual cost of setting and maintaining the

hydrant, and on the interest on the first cost of the hydrant itself.

The cost to the water taker of the larger pipe required for fire service beyond that required for domestic services only is considered offset by the valuable privileges which the water taker enjoys under the protection of the city. This is Municipal Ownership.

MR. ARTHUR A. REIMER. I would like to ask if the water department has to meet the sinking fund requirements for its bonded indebtedness.

MR. TIGHE. Yes; the water department meets and has always met these requirements, and the taxpayer never had to pay a cent as yet for or towards the water department. I would say, however, that in 1876 or 1877, or shortly after the water works became a municipal department, a sum of ten thousand dollars of the taxpayers' money was voted or appropriated by the city council to the water department, to pay for doing some work.

In 1900 this generosity of the city fathers was resurrected, and the result was that the water department had to pay back this ten thousand dollars together with interest at four per cent. What came near to being the best of the joke, on the water department, however, was the argument made that compound interest should be paid, and it was only the law of Massachusetts, which does not allow compound interest to be collected on debts, that prevented it.

MR. LEONARD METCALF. I would like to ask Mr. Tighe one thing, — whether it is not true that a considerable portion of the water debt has been paid off, so that the interest charges to-day are not predicated upon the value of the works to-day, but upon the outstanding bonds, — that is, the unpaid debt.

MR. TIGHE. I will answer the question by stating that the bonded debt is now greater than it ever was before. When the original bonds were paid off, new ones had been issued which increased the debt fifty thousand dollars.

MR. METCALF. I raised that point, Mr. President, for the reason that it would make a great difference whether a portion of the bonded debt had been paid off or not. Take it in my own little town of Concord, Mass.; the construction cost of the works now

amounts, without the improvements which were made last year or the year before, to something like two hundred and fifty thousand dollars. It is now somewhat greater. But I think the remaining debt was only something like ten or fifteen thousand dollars, so that there were no fixed charges to be met, to speak of. Of course the rates under those circumstances could be cut very substantially, it being apparent that the consumer had been taxed in the past years a sufficient amount to give a sinking fund which would retire the bonds in a comparatively short time. Now additional construction has been undertaken which has increased the debt, I think, something like twenty-five thousand dollars, which the consumer will have to bear; and in our town the sewerage works are maintained from the income of the water works, so that you could not compare the rates existing in Concord with those of any other town unless you made correction for a similar set of conditions.

MR. SULLIVAN. In order to get the matter clearly in my mind, I would like to ask Mr. Tighe what the total cost of his works was, and also what the amount of bonds now outstanding is, and whether they are paying interest just on the present amount of bonds or on the total cost of the works.

MR. TIGHE. We are paying interest on the bonds now outstanding. We are not, of course, paying interest on the bonds that have been paid off.

MR. SULLIVAN. What was the cost of the works, and what is the amount of bonds at the present time?

MR. TIGHE. I think the construction account is about a million and a half, and the first issue of bonds was $300 000 and the present issue is $350 000. We are now going to make another issue of $150 000 in order to raise money to pay for the construction of a new reservoir.

MR. METCALF. So you are paying on a total bond issue of how much?

MR. TIGHE. We are paying on a total bond issue of $350 000 at the present time.

MR. METCALF. That is the very question which I raised. You are paying, then, not upon the value of the works, but merely upon the remaining outstanding debt?

MR. TIGHE. Yes, upon the outstanding debt.

MR. METCALF. But upon a debt which has been cut down by excessive rates?

MR. TIGHE. No, but upon a debt that has been increased fifty thousand dollars. Our rates had never been excessive and were never within 70 per cent. of being as high as the rate of $18.00 mentioned above.

MR. SULLIVAN. Do I understand the final answer to be that you are now paying on $300 000 of bonds and have a $1 500 000 investment from which there is no interest being received?

MR. TIGHE. Yes. I might say that this interest is paid in dividends to the water takers in the form of cheaper water rates from time to time. Every decade or so, a reduction in the water rates has been made, which means a dividend to the water takers. For instance, last year the water takers got a dividend of $13 000, or they had to pay $13 000 less for water, which is the same thing.

The tax that the water department pays is based on the construction account. This tax amounted to over $22 000 last year, and was based on a value of a little over $1 500 000. It was not based upon the value of the outstanding bonds, but upon the total construction account of the works the same as if the works belonged to a private corporation.

THE PRESIDENT. I understood you to say, Mr. Tighe, that you earned seven or eight per cent. on your construction account; is that on the total cost of the works to date, or on your bonded debt?

MR. TIGHE. On the total cost of construction to date. I think there is a little over one hundred thousand dollars of income, and the cost of the works is about a million and a half; that is, the construction account amounts to that.

MR. METCALF. I wonder if Mr. Tighe would be good enough to throw a little more light on the matter of the hydrant rental. I am surprised at his statement that they estimate that the cost of the hydrant service is so low as $8.00 per hydrant. I know we looked into this question in connection with the Finance Commission investigation in Boston, and we found that it exceeded that amount very largely, and in the cases of private works which I have examined, the cost has always exceeded that amount very largely. I am surprised that the total cost of the hydrant service

should not be more than $8.00, which I understand him to state in his estimate.

MR. TIGHE. I had advocated that it should be $10.00, but it was made $8.00. This means the interest on actual cost of the hydrant only, the setting of it, and its maintenance.

MR. METCALF. Regardless of the additional cost of the pipe system?

MR. TIGHE. Certainly, regardless of the additional cost of the pipe system. In the discussion of the matter at the time between the representatives of the water department and the city proper, it was agreed that for the valuable privileges which the water taker enjoyed under the city, — that is, in being allowed to lay pipes through the streets and so on, police protection, and the credit of the city at his back, — the water taker ought, at least, to pay in return for the extra size of the pipe required for fire protection.

MR. THEODORE H. MCKENZIE. May I ask Mr. Tighe what he has done in Holyoke with reference to a sinking fund to provide for the renewal of the works. Ordinarily the depreciation on water works amounts to from three to five per cent. per annum, and I was wondering what they did about providing for reconstruction.

MR. TIGHE. We, of course, provide a sinking fund for the payment of bonds. Beyond this we do not make any provision because the creation and building up of a fund by one branch of a municipality in anticipation of future expenditures is a dangerous procedure unless such is protected by law.

It has been found, I think, where such has been attempted, that after a while, when the fund became any sizable amount, it was raided or wholly confiscated by the legislative body of the municipality and used for the more pressing needs of meeting the deficits in some of the other departments of the municipality.

In regard to renewals, I may say that these, together with extensions, are paid for out of the earnings of the department. For instance, this present year, and in the past two years, several thousand feet of 4-in. pipe, which was laid in the early days, have been replaced by new cast-iron pipe from 8 in. to 16 in. in diameter. So you see that the plant, instead of being allowed to depreciate,

is, on the contrary, being brought to a higher state of efficiency every year.

MR. WILLIAM MURDOCH.* I might say in a general way that we have no hydrant rental at all in the St. John water works, but a hydrant tax; that is, we assess the whole community according to the individual wealth. We take that method of letting the people know that they own the water works.

We have one schedule rate for supply and another schedule of taxation of values amounting to from one fourth to one fifth of one per cent. of the assessors' valuation, so that the assessment which we collect every year covers hydrant rentals and some other public services. As the city can't tax itself on values, we charge only the regular consumption rate on the city properties, such as ferries and public buildings, including the fire department buildings.

The cost of our works and plant, up to the present time, has been $2 071 070.79. The expenditure during last year was $156 053.42 and the income $181 868.67. Of the outgo, $22 394.00 went into sinking fund to retire debentures and $89 326.07 was paid in interest upon debentures, which varies from 3½ to 6 per cent.

The water department is a separate department from the assessment department and is what remains of what was originally a water company. It is a department of the city service, and it maintains its identity and assesses the citizens for the service. It is a self-sustaining department, and any money that remains over at the end of the year is placed in the sinking fund to redeem the bonds. I think our bond issues are very much like those the previous speaker has spoken of. When the time comes for them to be paid, we sometimes issue a new set and keep things alive in that way.

We have about 55 miles of distribution mains, varying in diameter from 1½ in. to 36 in., 420 fire hydrants, and 35 miles of service pipes supplying about 47 000 inhabitants.

The supply comes from two distinct sources, about 16 miles apart. This is in consequence of the city being in two parts, one on each side of the River Saint John, the depth of which is fully one hundred feet. A 12- and a 24-in. pipe supply the West Side, where the population is about 8 000, and the East Side is served through one 12- and two 24-in. mains.

* City Engineer, St. John, N. B.

PROCEEDINGS.

The Twenty-Ninth Annual Convention.

Rochester, N. Y., September 21, 22, 23, 1910.

The Twenty-Ninth Annual Convention of the New England Water Works Association was held at Rochester, N. Y., September 21, 22, and 23, 1910.

The headquarters of the Association were at Hotel Seneca, where the several sessions of the convention were held and the exhibits of the Association made.

On Tuesday evening a reception was tendered to members and guests at the Hotel Seneca by the local committee.

The following members and guests were present:

Honorary Member.

F. W. Shepperd.

Members.

J. W. Ackerman, S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, G. W. Batchelder, F. D. Berry, C. R. Bettes, H. R. Cooper, G. K. Crandall, C. E. Davis, M. J. Doyle, E. R. Dyer, E. D. Eldridge, B. R. Felton, E. A. Fisher, J. W. Graham, F. E. Hall, L. P. Hapgood, L. M. Hastings, W. C. Hawley, Allen Hazen, George Holtzmann, W. R. Hill, W. C. Hopper, W. E. Johnson, J. W. Kay, Willard Kent, G. A. King, J. J. Kirkpatrick, Morris Knowles, Emil Kuichling, B. C. Little, F. H. Luce, Daniel McDonald, D. B. McCarthy, T. H. McKenzie, A. E. Martin, John Mayo, Leonard Metcalf, William Murdoch, F. L. Northrop, H. D. Pease, E. M. Peck, T. A. Pierce, A. E. Pickup, R. W. Pratt, J. F. Reagan, Jr., A. A. Reimer, Henry Roberts, G. A. Sanborn, P. R. Sanders, W. J. Sando, A. L. Sawyer, E. M. Shedd, J. E. Sheldon, G. H. Snell, J. F. Sprenkel, G. A. Stacy, G. T. Staples, W. F. Sullivan, D. G. Thomas, R. J. Thomas, J. L. Tighe, J. A. Tilden, J. G. Trautwine, Jr., J. H. Walsh, Hardolph Wasteneys, R. S. Weston, G. E. Winslow, I. S. Wood. — 72.

Associates.

American Asphaltum and Rubber Company, by Ray B. Nisbet; Anderson Coupling Company, by C. E. Pratt; Ashton Valve Company, by Columbus Dill and C. W. Houghton; Builders Iron Foundry, by A. B. Coulters; Chap-

man Valve Manufacturing Company, by H. L. DeWolfe, A. W. Hobbs, J. M. Noonan, A. W. Gilbert, and Thos. Rudley; Allyne Brass Foundry Company, by B. Thos. Beardsley, R. M. Corcoran, C. R. Bohn, and J. N. Frantz; Darling Pump and Manufacturing Company, by H. H. Davis and J. L. Hough; Gamon Meter Company, by C. A. Vaughan, W. H. Buckley, E. W. Gamon; George E. Gilchrist Company, by W. J. Chellew; Glauber Brass Manufacturing Company, by A. I. Fischer and Sam Davis; Hays Manufacturing Company, by C. E. Mueller, H. H. Clemens, and T. J. Nagle; Hersey Manufacturing Company, by L. S. Barnard, W. A. Hersey, W. C. Sherwood, Frank Whitlock, and J. A. Tilden; International Steam Pump Company, by Samuel Harison, D. A. Acer, A. Neidemeyer, and D. A. Decrow; Kennedy Valve Company, by M. J. Brosnan; Lead Lined Iron Pipe Company, by Thomas Dwyer and J. W. McCormack; Ludlow Valve Manufacturing Company, by T. A. Galvin and A. R. Taylor; Chas. Millar & Son Company, by C. F. Glavin; H. Mueller, Manufacturing Company, by G. A. Caldwell, R. M. Hastings, F. B. Mueller, O. B. Mueller, and T. G. Paradine; National Meter Company, by W. P. Oliver, J. G. Lufkin, John C. Kelley, Jr., and C. H. Baldwin; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by J. F. Reagan, Jr., F. A. Smith, T. D. Faulks, and H. H. Kinsey; New York Continental Jewell Filtration Company, by R. E. Milligan; Norwood Engineering Company, by H. W. Hosford; Pittsburg Meter Company, by J. M. Jones, V. E. Arnold, T. C. Clifford, and F. L. Northrop; Platt Iron Works Company, by F. H. Hayes; Rensselaer Manufacturing Company, by F. S. Bates, C. L. Brown, and J. S. Warde, Jr.; Ross Valve Manufacturing Company, by W. R. Ross and J. C. Ross; A. P. Smith Manufacturing Company, by F. N. Whitcomb and T. F. Halpin; Thomson Meter Company, by E. M. Shedd, W. S. Cetti, and S. D. Higley; Union Water Meter Company, by L. P. Anderson and F. E. Hall; U. S. Cast Iron Pipe and Foundry Company, by W. H. Franklin; Water Works Equipment Company, by W. H. Van Winkle and H. M. Heim; R. D. Wood & Co., by W. F. Woodburn and C. R. Wood; Standard Cast-Iron Pipe and Foundry Company, by W. E. Dodds. — 79.

GUESTS.

Mrs. E. M. Finigan and Miss B. Moran, Lyons, N. Y.; Mr. and Mrs. Pailsey, Mr. and Mrs. John F. Skinner, Frederick T. Elwood, Mrs. Beekman C. Little, H. S. Judson, George A. Beach, H. L. DeLaney, Thos. J. Neville, George H. Bliven, G. K. M. Clarke, Jos. E. Putnam, Ruden W. Post, Miss Mamie Miller, Mrs. George Miller, Mrs. George Cripps, David H. Westbury, Mr. and Mrs. John F. Amos, Mrs. E. A. Fisher, Miss Fanny B. Fisher, N. Adelbert Brown, F. L. Pease and Montgomery E. Leary, Rochester, N. Y.; John A. Hamilton, Paterson, N. J.; Mr. and Mrs. Alex Milne, St. Catherines, Ont.; Mrs. D. G. Thomas, Denver, Colo.; C. H. Ross, Waterloo, N. Y.; B. F. Sonder, Atlantic City, N. J.; Norman J. Gould, Seneca Falls, N. Y.; Frank Anigoni, Middletown, Conn.; Mr. and Mrs. W. Calahan, John H.

Shifferens, Mrs. A. Neidermeyer, Miss Neidermeyer, Henry L. Lyons, W. E. Glass, Edward A. Ritter, George M. Schmich and Mrs. Charles E. Richardson, Buffalo, N. Y.; Mrs. George Holtzmann, Schenectady, N. Y.; Ray Douglass, George R. Ellis, Canandaigua, N. Y.; Mrs. F. C. Luce, Woodhaven, N. Y.; Mrs. H. W. Hosford, Norwood, Mass.; C. J. Biladeau, J. F. Biladeau, Pittsfield, Mass.; Mrs. J. W. Kay, Milford, Mass.; John K. Gunn, Utica, N. Y.; C. P. Pollard, Jr., I. E. Stansbury, Baltimore, Md.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. T. J. Carmody, Miss Mary T. Ryan, Holyoke, Mass.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. George T. Staples, Dedham, Mass.; Mrs. R. J. Thomas, Lowell, Mass.; Mrs. John Mayo, Bridgewater, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. I. S. Wood, Providence, R. I.; Mrs. George A. Stacy, Marlboro, Mass.; Mrs. T. A. Pierce, Mrs. Emma A. Vaughan, East Providence, R. I.; Mrs. Columbus Dill, T. A. Collins, Miss J. M. Ham, Boston, Mass.; Mr. and Mrs. J. J. Desmond, Lawrence, Mass.; A. E. Kornfeld, I. S. Holbrook, E. T. Walker, J. M. Goodell, Mrs. F. W. Shepperd, New York City; D. C. Barrows, Olean, N. Y.; Mrs. J. C. Ross, Mrs. James M. Caird, Mrs. Fred S. Bates, Troy, N. Y.; Mr. and Mrs. A. W. P. Cobb, Auburn, Me.; Mr. and Mrs. J. B. Longley, Lewiston, Me.; C. A. Goodhue, Thompsonville, Conn.; Mr. and Mrs. James P. Bacon, Mrs. L. M. Hastings, Cambridge, Mass.; Joseph Alger, Brockton, Mass.; Mrs. L. P. Hapgood, Springfield, Mass.; Mrs. Ernest Gamon, Newark, N. J.; Mrs. Charles R. Wood, Philadelphia, Pa.; Henry V. Van Order, Ithaca, N. Y. — 95.

Total members and guests present, 246.

The following had exhibits:

MEMBERS.

Geo. T. Staples.
Geo. H. Snell.
Geo. E. Winslow.
E. R. Dyer.
A. S. Sawyer.
Frank E. Merrill.
H. B. Van Order.

ASSOCIATE.

H. Mueller Manufacturing Company.
Geo. E. Gilchrist Company.
Glauber Brass Manufacturing Company.
Union Water Meter Company.
Allyne Brass Foundry Company.
R. D. Wood & Co.
The Pitometer Company.

The Ashton Valve Company.
Hersey Manufacturing Company.
Neptune Meter Company.
American Ashphaltum and Rubber Company
The Gamon Meter Company.
Henry R. Worthington Company.
Alexander Milburn Company.
Chapman Valve Manufacturing Company.
National Water Main Cleaning Company.
Water Works Equipment Company.
Lead Lined Iron Pipe Company.
Thomson Meter Company.
Pittsburg Meter Company.
Ross Valve Manufacturing Company.
Hays Manufacturing Company.
Builders Iron Foundry.
National Water Meter Company.
A. P. Smith Manufacturing Company.
Norwood Engineering Company.

ROCHESTER INDUSTRIES.

Eastman Kodak Company.
Bausch & Lomb Optical Company.
Luitwieler Pumping Engineering Company.
Taylor Instrumental Companies.
Gleason Works.
Rochester Water Department.

FORENOON, WEDNESDAY, SEPTEMBER 21.

The convention was called to order at 10.30 A.M., by George A. King, President. His Honor Mayor Hiram Edgerton was presented, and made a short address of welcome, as follows.

Mr. President and Gentlemen of the New England Water Works Association, — The city of Rochester cordially welcomes all visitors, and it has been my privilege upon many occasions to extend the greetings of my fellow-citizens to gatherings of this character. We feel honored in having with us so many distinguished people as are connected with this organization. Our invitation and our welcome is not, however, entirely unselfish, for we expect to learn from you many things which will be of benefit to us. In return, we are willing to give you the best we

have. We have a beautiful city, and we are very proud of it. We are glad to have you here at a time when we can show the city to you under such favorable circumstances. We trust that your visit among us will be not only pleasant but profitable, and that you will receive such impressions as will cause you to remember us with pleasure and wish to come back again. We give you a most cordial welcome, and, so far as is possible, we extend to you also the freedom of the city, to go where you will, when you will, — and we know you will be welcomed everywhere.

THE PRESIDENT. Mr. Mayor, I thank you for your words of welcome, and we shall be pleased to accept your courtesies. We have with us another representative of the city of Rochester, the secretary of the Chamber of Commerce, Mr. Roland B. Woodward.

MR. WOODWARD. *Mr. President and Gentlemen,* — My experience with water-works conventions is limited, but very vivid. I went to Milwaukee to a meeting of the American Water Works Association, and if I ever saw a gathering which belied its name, that one did. I didn't recover from the effects of my attendance in time to go to the last meeting at New Orleans. They are coming to Rochester next year, as you know, and we will show them the finest system of water works that they have ever seen, although they can dilute the water if they want to.

But everybody who comes to Rochester has a good time, and we don't want you people to be any exception to the rule. There is something about the atmosphere of this city that is exhilarating, and after you have been here two or three days we hope you will feel just like old-time Rochesterians. That is the spirit of our city: A spirit of open-hearted and open-handed hospitality, and we are glad to have you here. The mayor has tendered you a welcome in behalf of the city, and I take pleasure in welcoming you in behalf of the business interests of the city, which I represent through the Chamber of Commerce. Our invitations have gone to different organizations, and we have welcomed here the Jew and Gentile, the Catholic and the Protestant, representatives of business interests at home and abroad, — in fact, we have had among us all types and kinds of men, and we have yet to hear of any gathering in this city that has not received fair and courteous treatment. We know that you will have a good time, and we know

that we will leave nothing undone which will help you to have a good time. We are proud of our city, we are proud of the people who visit us, and we want them to go away feeling that this is a fine city in which to visit or in which to live. We hope that some of you will find this place so attractive that you can appreciate the feelings of one man who, after having spent a few days here, said : " It has always worried me somewhat as to where I should go if I died and couldn't get into heaven, but now my mind is at rest. If I went up there and applied for admission and St. Peter said, ' No, you can't come in,' I should simply say, ' All right, never mind; I will just go back to Rochester.' "

After thanking Mr. Woodward for his words of welcome, the President called upon the Secretary, who read the following names of applicants for membership, properly endorsed and recommended by the Executive Committee:

Active: Joseph F. Biladeau, Pittsfield, Mass., superintendent; Chester Gordon Gillespie, Berkeley, Cal., engaged in the designing and operation of water filtration plants; Richard R. Bradbury, West Shokan, N. Y., section engineer, Board of Water Supply, New York City; Charles Henry Preston, Jr., Waterbury Conn., civil engineer; William E. Hannon, Boston, Mass., water commissioner; Leslie O. Smith, Columbus, Ohio, engaged in physical and auditing examination and superintending of water works; George R. Ellis, Canandaigua, N. Y., superintendent of water department; Henry B. Van Order, Ithaca, N. Y., superintendent of meters; George L. Weller, Elyria, Ohio, superintendent water works. — 9.

Associate: Allyne Brass Foundry Company, Detroit, Mich.; Standard Cast-Iron Pipe and Foundry Company, Bristol, Pa.; Kickerbocker Engineering Company, Brooklyn, N. Y. — 3.

On motion of Lewis M. Bancroft, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so they were declared by the President to be duly elected members of the Association.

On motion of Mr. James L. Tighe, it was voted that the President be authorized to appoint a committee of five to nominate officers for the ensuing year, and the President appointed as the committee, James L. Tighe, M. N. Baker, R. S. Weston, J. C. Hammond, Jr., and R. C. P. Coggeshall.

THE PRESIDENT. Some two months ago I was asked, as President of the Association, to appoint delegates to attend the Second National Conservation Congress at St. Paul, and I appointed as our delegates Mr. J. F. Fanning, of Minneapolis; J. W. Alvord, of Chicago; G. H. Benzenberg, of Milwaukee; D. W. Meade, of Madison; and J. Robert Adams, of St. Paul. These gentlemen all accepted the appointment, and I have received the following letter from Mr. Benzenberg.

MILWAUKEE, September 12, 1910.

Mr. GEO. A. KING, *Prest. N. E. W. W. Assoc.*,
TAUNTON, MASS.

Dear Sir,—I wish to report that I attended the Second National Conservation Congress at St. Paul last week, together with Professor D. W. Meade. I did not have the pleasure of meeting the other delegates appointed by you.

Enclosed I send you a copy of the program for the week. Comparatively little was accomplished by the congress, most of the time being taken up by the speakers on the question of state rights versus the right of the federal government to develop and control the natural resources, and by addresses. Aside from that by the president and that by Mr. Roosevelt, — which may be useful for political purposes, — very little of a really practical nature was submitted. The representatives of technical societies did not constitute a factor of the congress. I will send you or the Secretary, as you may direct, a complete copy of all the proceedings of the congress as soon as the same are printed and bound, which will be in about three months from now.

Hoping you will have a very successful meeting at Rochester, I remain,

Very truly yours,

G. H. BENZENBERG.

I directed Mr. Benzenberg to send his copy of the proceedings to our headquarters at Boston, and if any of you wish to consult the volume at any time you will find it there after it is issued.

MR. GEORGE A. STACY. *Mr. President,* — I desire to make a motion at this time in regard to a kindred association. I move that the Secretary be instructed to send this telegram: "The New England Water Works Association, in convention assembled at Rochester, N. Y., September 21, 1910, to the Central Water Works Association assembled at its thirteenth annual convention, sends greetings and congratulations." [Adopted.]

The President announced that the Executive Committee had considered somewhat the matter of the place for the next annual

convention, and had appointed a subcommittee consisting of the President, the Secretary, and Mr. Allen Hazen, to look into the subject. The committee would be pleased to receive suggestions at any time.

EVENING.

The following papers were read at the evening session:

"A General Description of Rochester, Its Municipal Government and Physical Features," by Mr. Edwin A. Fisher, city engineer, Rochester, N. Y.; "Pertinent Matters relating to Water Works," by Mr. Frederick T. Elwood, commissioner of public works, Rochester, N. Y.; "A Description of the Rochester Water Works," by Mr. Beekman C. Little, superintendent of water works, Rochester, N. Y.; "New Reservoir at Cobb's Hill" (illustrated), by Mr. John F. Skinner, principal assistant engineer, Rochester, N. Y.

An address was then made by Mr. R. N. Searles, vice-president of the Chamber of Commerce, upon the "Rochester Spirit."

Mr. C. C. Laney, superintendent of parks, Rochester, N. Y., gave a brief description of the Rochester park system, and showed a number of stereopticon views of scenes in the various parks.

[Adjourned to 10 A.M., Thursday, September 22.]

THURSDAY MORNING, SEPTEMBER 22.

The Secretary read the following telegram received from the Central States Water Works Association: "We acknowledge with grateful appreciation receipt of your telegram of kind greetings. The Central States Water Works Association return to your assembly now in session at Rochester, N. Y., their cordial greetings, and wish you the fullest measure of success in your good work."

Mr. Emil Kuichling, consulting engineer, New York, read a paper on "Steel Pipe Lines." The paper was discussed by Mr. Francis H. Luce, Mr. Edwin A. Fisher, Mr. William Murdock, Mr. Leonard Metcalf, Mr. L. M. Hastings, Mr. W. C. Hawley, Mr. Allen Hazen, Mr. Morris Knowles, and Mr. Robert S. Weston.

In the absence of Mr. F. C. Jordan, secretary of the Indianapolis Water Company, Indianapolis, Ind., who was in attendance

at the convention of the Central States Water Works Association, Mr. Leonard Metcalf read Mr. Jordan's paper on "Statistics of Growth of Income." The paper was discussed by Mr. Metcalf, Mr. W. C. Hawley, Mr. William F. Sullivan, Mr. James L. Tighe, Mr. Arthur A. Reimer, Mr. Theodore H. McKenzie, and Mr. William Murdock.

AFTERNOON.

Mr. William F. Woodburn, chairman of the Committee on Exhibits, made the following report.

"We have 26 exhibits from the associate members, 8 exhibits from the active members, and 5 exhibits from city of Rochester industries. The exhibits of the active members and of the city of Rochester industries have added a great deal of interest to the general exhibition. This has been a new feature this year, and it will undoubtedly be continued in the future. The associate members have given us a very nice line of exhibits. I wish to say that the local committee have been very kind. They attended to all the trucking and unpacking, so that the exhibitors have had very little bother. We are particularly indebted to the Rochester Water Department for these courtesies, and we thank them for it."

On motion of Mr. Reimer, it was voted that the report be accepted and placed on the minutes. The President, in discharging the committee, extended the thanks of the Association for its efficient service in providing one of the most interesting exhibitions the Association has ever had.

Mr. Leonard Metcalf, consulting engineer, Boston, Mass., then read a paper on "Depreciation in Water Works and Methods of Accounting Therefor." This paper was discussed by Mr. Arthur A. Reimer, Mr. Theodore H. McKenzie, Mr. James L. Tighe, Mr. Edward S. Cole, Mr. William S. Sullivan, Mr. Emil Kuichling, and the President.

Mr. Robert Spurr Weston, sanitary expert, Boston, Mass., read a paper on "Corrosion of Metals." At the conclusion of the reading of the paper by Mr. Weston, the President said:

"Some three months ago, in conversation with one of our members, Mr. Allen Hazen, in New York, he said he hoped that we might hear something at our convention about the effect of

hypochlorite of lime upon pipe, and suggested that some experiments had been made in New York, and that by writing to Mr. Wiggin I might obtain a contribution to the discussion of that subject. I received this noon the following letter:

NEW YORK, September 21, 1910.

Mr. GEORGE A. KING, *President New England Water Works Association*, ROCHESTER, N. Y.

Dear Sir, — Complying with your request to Mr. Wiggin, which he has referred to me, to take part in the discussion of Mr. Weston's paper on "Corrosion of Metals," I take pleasure in sending you herewith a statement of what data we have gathered regarding the effects of hypochlorite of lime on metals.

Yours truly,

HAROLD C. STEVENS.

Mr. Stevens's paper was read by Mr. James L. Tighe, and both papers were then discussed by Mr. Edward D. Eldredge, Mr. Samuel A. Agnew, Mr. Weston, Mr. W. G. Hawley, and Mr. William F. Sullivan.

EVENING.

The following-named applicants were elected to membership, the Secretary casting the ballot of the Association: John M. Goodell, of New York, editor *Engineering Record*, active; The Gould Manufacturing Company, Seneca Falls, N. Y., associate.

Mr. Morris Knowles, chief engineer, Bureau of Filtration, Pittsburg, Pa., read a paper entitled, "The Use of the Water Ejector for Transporting Sand." Mr. Chester F. Drake, superintendent of filtration, Pittsburg, contributed a paper upon the same subject, which was read by Mr. W. C. Hawley. The subject was discussed by Mr. M. F. Collins and Mr. Allen Hazen.

At the conclusion of the discussion, the President announced that Mr. William F. Sullivan had a motion to make. Mr. Sullivan said:

"*Mr. President*, it seems to me that the committee whose duty it was to select a meeting place for this convention certainly made no mistake in selecting the city of Rochester, and I believe I express the feelings of the Association when I say that the people of Rochester have surely done their part to make our visit here pleasant and profitable.

"I therefore move that a rising vote of thanks be extended to the officials of the water department, to the city engineer, to the Chamber of Commerce, and to all who have in any way contributed to our instruction, entertainment, and pleasure; and that the Secretary of the Association be instructed to send to the proper persons an expression of our appreciation of the generous hospitality which has been shown us." [Adopted.]

Dr. Herbert D. Pease, sanitary expert, Board of Water Supply, New York City, gave a talk on "The Relation of Flies to the Transmission of Infectious Diseases." His address was illustrated by stereopticon views.

A paper by Professor H. T. Barnes, director of physics, McGill University, Montreal, Canada, on "Ice Formation," was read by title.

Mr. James M. Caird, chemist and bacteriologist, Troy, N. Y., read a paper on "The Purification Plant of the Rochester and Lake Ontario Water Company, Rochester, N. Y." Dr. J. Roby, of Rochester, Mr. W. C. Hawley, Mr. Emil Kuichling, and Mr. Leonard Metcalf contributed to the discussion. [Adjourned.]

November Meeting.

Hotel Brunswick,
Boston, November 9, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

Members.

S. A. Agnew, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, C. A. Bogardus, G. A. P. Bucknam, G. A. Carpenter, George Cassell, J. C. Chase, J. H. Child, C. E. Childs, E. S. Cole, M. F. Collins, W. R. Conard, L. S. Doten, E. D. Eldredge, G. H. Finneran, J. H. Flynn, A. N. French, C. W. Gilbert, A. S. Glover, F. H. Gunther, R. K. Hale, F. E. Hall, J. O. Hall, W. E. Hannan, Allen Hazen, M. F. Hicks, F. M. Hutchinson, W. S. Johnson, Willard Kent, F. C. Kimball, G. A. Kimball, G. A. King, J. J. Kirkpatrick, Morris Knowles, E. E. Lochridge, A. R. McCallum, W. A. McKenzie, N. A. McMillen, D. E. Makepeace, A. D. Marble, A. E. Martin, John Mayo, F. E. Merrill, Leonard Metcalf, E. E. Minor, William

Naylor, F. L. Northrop, O. E. Parks, T. A. Peirce, L. C. Robinson, M. J. Rosenau, H. W. Sanderson, A. L. Sawyer, E. M. Shedd, J. E. Sheldon, G. H. Snell, G. A. Stacy, G. T. Staples, E. L. Stone, W. F. Sullivan, H. L. Thomas, R. J. Thomas, W. H. Thomas, J. L. Tighe, J. A. Tilden, D. N. Tower, W. H. Vaughan, C. K. Walker, R. S. Weston, F. I. Winslow, G. E. Winslow, L. S. Wood. — 76.

ASSOCIATES.

American Asphaltum and Rubber Company, by R. B. Nisbet; Ashton Valve Company, by C. W. Houghton; Harold L. Bond & Co., by H. L. Bond and G. S. Hedge; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; Hersey Manufacturing Company, by Albert S. Glover, J. A. Tilden, W. A. Hersey; International Steam Pump Company, by Samuel Harrison; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by H. F. Gould and A. R. Taylor; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin and J. G. Lufkin; Pennsylvania Cement Company, by G. M. Clukas; Neptune Meter Company, by H. H. Kinsey; Pittsburg Meter Company, by F. L. Northrop; Rensselaer Manufacturing Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd, United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Union Water Meter Company, by E. P. King and F. E. Hall; R. D. Wood & Co., by William Woodburn. — 27.

GUESTS.

C. O. Bent, Gardner, Mass.; Clifton A. Crocker, Stanford L. Haynes, Springfield, Mass.; Dr. John F. Cahill, A. Fleming, J. J. Desmond, Lawrence, Mass.; C. A. Moore, Westfield, Mass.; Henry E. Warren, Ashland, Mass.; E. J. Titcomb, Rochdale, Mass.; F. D. Flynn, Canal Zone; J. W. Stinson, Cambridge, Mass.; John Thompson, Dracut, Mass.; George T. Palmer, F. E. Lenene, Boston, Mass. — 14.

The Secretary presented the following names of applicants for membership, all of whom had been approved by the Executive Committee.

Active. — Channing Smith, Cherry Valley, Mass., chairman of Board of Water Commissioners, Cherry Valley and Rochdale Water District; E. J. Whitcomb, Rochdale, Mass., member of Board of Water Commissioners, Cherry Valley and Rochdale District; Wisner Martin, Cambridge, Mass., for eleven years principal assistant engineer, Department of Public Works, New York City, now engineer to the Joint Water Board of Abington and Rockland, Mass. — 3.

On motion of Mr. T. A. Peirce, the Secretary was directed to cast the ballot of the Association in favor of the admission of the applicants above named, and he having done so, they were declared by the President duly elected to membership.

Dr. John C. Cahill, mayor of the city of Lawrence, then addressed the Association on water-works topics, with especial reference to the construction and work of the Lawrence filter.

Mr. Edward S. Cole, C.E., of New York, read a paper on the subject of "Water Consumption and Statistics relating Thereto." The discussion which followed was participated in by Mr. Leonard Metcalf, Mr. Elbert E. Lochridge, Mr. George A. Stacy, the President, Mr. George A. Carpenter, Mr. Frank C. Kimball, Mr. Johnson, Mr. Allen Hazen, Mr. Frank A. McInnes, Mr. Robert S. Weston, Mr. John C. Chase, Mr. Samuel A. Agnew, Mr. F. H. Hayes, Mr. William S. Sullivan, Mr. Walter H. Richards, Mr. George Cassell, Mr. Robert J. Thomas, Mr. John J. Kirkpatrick, and Mr. George E. Winslow.

Mr. Allen Hazen, consulting engineer, of New York, presented a paper in which he considered the subject of the reasonable thickness of the walls of pipes in order to afford requisite strength. Mr. Leonard Metcalf, the President, and Mr. Robert S. Weston spoke in connection with the paper.

MR. A. E. MARTIN.* Mr. President, it seems to me that neither Mr. Hazen's paper nor Mr. Cole's paper, especially Mr. Hazen's, should be buried in our files without some further action being taken upon them. If our pipe specification tables are not what they should be, they certainly ought to be changed. I should like to inquire if our Committee on Pipe Specifications is still in existence, and if it is not, it seems to me it ought to be revived and this paper of Mr. Hazen's referred to it.

THE PRESIDENT. I understand, Mr. Martin, that the Committee on Standard Specifications for Cast-Iron Pipe, of which Mr. Brackett is the chairman, is still in existence.

MR. MARTIN. Then I will make this motion: That Mr. Hazen's paper be referred to the Committee on Standard Specifications for Cast-Iron Pipe for study and further report, unless Mr. Hazen has some objection to that.

* Superintendent of Water Works, Springfield, Mass.

The motion was adopted.

MR. JOHN O. HALL. I think that the matter which Mr. Cole has presented is also one of very great importance, and one which lies at the root of the financial element which enters into the question of water distribution. I will therefore move that his paper be referred to a committee of three, to be appointed by the chair, and reported upon.

The motion was adopted, and the President appointed as such committee: Mr. Leonard Metcalf, Mr. Frank J. Gifford, and Mr. William F. Sullivan.

Adjourned.

DECEMBER MEETING.

HOTEL BRUNSWICK,
BOSTON, December 14, 1910.

The President, George A. King, in the chair.

The following members and guests were present:

HONORARY MEMBER.

Frederic P. Stearns.

MEMBERS.

E. R. B. Allardice, C. H. Baldwin, A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, J. W. Blackmer, C. A. Bogardus, George Bowers, Dexter Brackett, James Burnie, G. A. Carpenter, J. C. Chase, R. D. Chase, C. E. Childs, R. C. P. Coggeshall, M. F. Collins, A. W. Cuddeback, J. C. DeMello, Jr., John Doyle, E. D. Eldredge, J. H. Flynn, A. N. French, F. L. Fuller, A. S. Glover, F. H. Gunther, F. E. Hall, T. G. Hazard, Jr., H. R. Johnson, W. S. Johnson, F. T. Kemble, Willard Kent, Patrick Kieran, S. E. Killam, F. C. Kimball, G. A. Kimball, G. A. King, C. F. Knowlton, A. R. McCallum, F. A. McInnes, N. A. McMillen, D. E. Makepeace, W. E. Maybury, John Mayo, F. E. Merrill, Leonard Metcalf, William Naylor, F. L. Northrop, O. E. Parks, E. M. Peck, T. A. Peirce, H. E. Perry, W. D. Pollard, Dwight Porter, Henry Roberts, L. C. Robinson, H. E. Royce, A. L. Sawyer, W. H. Sears, E. M. Shedd, G. H. Snell, G. A. Stacy, T. V. Sullivan, W. F. Sullivan, G. T. Swarts, H. A. Symonds, L. A. Taylor, R. J. Thomas, L. D. Thorpe, E. J. Titcomb, D. N. Tower, C. H. Tuttle, W. H. Vaughn, L. J. Wilber, F. B. Wilkins, F. I. Winslow, G. E. Winslow, I. S. Wood. — 78.

ASSOCIATES.

Ashton Valve Company, by H. H. Ashton and C. W. Houghton; Harold L. Bond Company, by F. M. Bates; Chapman Valve Manufacturing Company, by H. L. DeWolfe; Darling Pump and Manufacturing Company, by H. H. Davis; Hayes Machinery Company, by F. H. Hayes; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; International Steam Pump Company, by Samuel Harrison and S. F. Nye; Lead-Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor and H. F. Gould; Chas. Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; Neptune Meter Company, by H. H. Kinsey; New York Continental Jewell Filtration Company, by R. E. Miliigan; Rensselaer Manufacturing Company, by C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; United States Cast Iron Pipe and Foundry Company, by D. B. Stokes; Waldo Bros., by H. E. Browne; R. D. Wood & Co., by W. F. Woodburn. — 26.

GUESTS.

Samuel F. Crompton, engineer, East Greenwich, R. I.; A. M. Dunbar, water commissioner, Hyde Park, Mass.; F. F. Strout, J. H. A. Currier, F. H. Fay, H. A. Hanscom, Louis K. Rourke, and C. F. Wentworth, Boston, Mass.; F. E. Strickland, Wm. E. Atwater, and John E. Boyle, Westfield, Mass ; J. J. Desmond, Lawrence, Mass.; Samuel H. Lea, state engineer, Pierre, So. Dak.; G. H. Pratt, chemist, Rhode Island State Board of Health, Providence, R. I.; Thomas S. O. Connell, water commissioner, Wakefield, Mass. — 15.

The Secretary presented applications for membership, properly endorsed and approved, from Herbert P. T. Matte, Southbridge, Mass., assistant superintendent engineer, Southbridge Water Supply Company, and J. W. Speller, Pittsburg, Pa., chief chemist and metallurgical engineer for the National Tube Company.

On motion of Mr. Peirce, the Secretary was instructed to cast the ballot of the Association in favor of the applicants, and he having done so, they were declared by the President duly elected members.

Louis K. Rourke, superintendent of streets, Boston, Mass., gave an interesting talk, illustrated by stereopticon views, on the Panama Canal. Mr. John C. Chase, Mr. Frank L. Fuller, and Mr. Frederic P. Stearns spoke briefly of visits made by them to the work.

Mr. Robert E. Milligan, manager of the New York Continental Jewell Filtration Company, read a paper on "The Water Filtration Plant at Newport, R. I." He was followed by Dr. Gardner T. Swarts, secretary of the State Board of Health of Rhode Island, whose subject was "Some Difficulties in the Purification of Water Supplies." The discussion was participated in by Mr. Pratt, Mr. Harry W. Clark, Mr. Robert S. Weston, and Mr. Leonard Metcalf. Dr. Swarts and Mr. Milligan spoke in reply.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of Executive Committee of the New England Water Works Association at Hotel Seneca, Rochester, N. Y., Wednesday, September 21, at 9.30 P.M.

Present: President George A. King, Allen Hazen, Michael F. Collins, Irving S. Wood, George A. Stacy, L. M. Bancroft, Robert J. Thomas, and Willard Kent.

Voted: That the following-named members and associates who were dropped for non-payment of dues, having since settled the same, be, and hereby are, reinstated:

Members: Messrs. T. W. Lesage, G. C. Bunker, R. S. Lea, B. R. Felton, E. P. Whitten, J. W. DuB. Gould, C. H. Rollins, R. W. Pratt, T. D. L. Coffin, W. H. Humphreys, A. J. Taylor, B. B. Hodgman, E. A. Weimer, and H. A. Lord.

Associates: Hart Packing and Pitometer Company.

Voted: That the following-named applications for membership and associate membership be, and hereby are, recommended for admission:

For membership: Charles H. Preston, Jr., civil and consulting engineer, Waterbury, Conn.; William E. Hannan, water commissioner, Boston, Mass.; Joseph F. Biladeau, superintendent water works, Pittsfield, Mass.; George L. Weller, superintendent water works, Elyria, Ohio; Chester G. Gillespie, Berkeley, Cal.; Richard R. Bradbury, West Shokan, N. Y.; George R. Ellis, superintendent water department, Canandaigua, N. Y.; Leslie C. Smith, superintendent water works, Cleveland, Ohio; Henry B. Van Order, superintendent water works, Ithaca, N. Y. — 9.

For associate membership: Knickerbocker Engineering Company, New York City; Allyne Brass Foundry Company, Detroit, Mich.; and Standard Cast Iron Pipe and Foundry Company, Bristol, Pa. — 3.

The question of the location for the next annual convention was discussed, and it was voted that the President, Vice-President

Hazen, and Secretary Kent be, and hereby are, appointed a committee to recommend a place for holding the annual convention of 1911, any necessary expense incurred by the committee to be borne by the Association.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Seneca, Rochester, N. Y., September 22, 1910.

Present: President George A. King, Allen Hazen, Michael F. Collins, Leonard Metcalf, Irving S. Wood, George W. Batchelder, and Willard Kent.

The following applications were received and recommended for admission:

For membership: John M. Goodell, editor *Engineering Record*, New York City.

For associate membership: Gould Manufacturing Company, Seneca Falls, N. Y.

For reinstatement to membership: Mrs. E. M. Finigan, secretary Lyons Water Company, Lyons, N. Y.

Bill rendered Mr. Arthur T. Safford for extra copies of report of committee appointed to collect data relating to awards for water and water-power diversion was, by vote, rebated.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Brunswick, Boston, Mass., November 9, 1910, at 12 M.

Present: President George A. King, Allen Hazen, Richard K. Hale, Lewis M. Bancroft, George A. Stacy, Leonard Metcalf, Robert J. Thomas, Irving S. Wood, and Willard Kent.

Three applications were received and recommended for admis-

sion, namely, for membership: Wisner Martin, civil engineer, Cambridge, Mass.; Channing Smith, water commissioner, Cherry Valley, Mass.; E. J. Titcomb, water commissioner, Rochdale, Mass.

Voted: That the President be and hereby is authorized to appoint a committee to consider the needs of the library of the Association. The President appointed as that committee Messrs. Charles S. Sherman, Richard K. Hale, and George A. Sampson.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at Hotel Brunswick, Boston, Mass., Wednesday, December 14, 1910, at 12 M.

Present: President George A. King and members Michael F. Collins, Leonard Metcalf, Irving S. Wood, George A. Stacy, George W. Batchelder, Willard Kent, Lewis M. Bancroft, and Robert J. Thomas.

Two applications were received and recommended for admission, namely:

For membership: F. N. Speller, chemist, Pittsburg, Pa., and Herbert P. T. Matte, assistant superintendent Southbridge Water Supply Company, Southbridge, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

BOOK REVIEWS.

SEWERAGE. THE DESIGNING, CONSTRUCTION, AND MAINTENANCE OF SEWERAGE SYSTEMS. By A. Prescott Folwell, editor *Municipal Journal and Engineer*. Sixth edition, revised and enlarged. 8vo, x + 506 pages, 46 figures, and 12 plates. New York: John Wiley & Sons, 1910. Cloth, $3.00.

While this book was primarily intended for practicing engineers, it is admirably adapted to use as a text-book in engineering schools.

The book is divided into four parts, the first three, designing, construction, and maintenance, dealing more directly with the sewerage system, the fourth with sewage disposal.

Under "Designing," the author discusses different types of systems, the amount of sewage, rainfall and run-off data, with the necessary sizes of sewers and questions of flushing and ventilation. There is then a statement of the surveys, borings, etc., that are necessarily made before the actual design of the system can be carried out.

The author then discusses the detailed design of the system and preparation of plans, with many illustrations of existing works. This first part of the book closes with an excellent chapter on contracts, specifications, and estimates of costs, with notes on the question of assessments. It includes nearly one half of the book.

Part II, "Construction," deals with the necessary preliminary work, engineering and otherwise, giving lines and grades, the inspection and measurement of the work, closing with a long chapter on the details and methods of construction.

The third part, "Maintenance," is a brief statement of the work required to keep the system in proper running order, with the necessary flushing, cleaning, etc.

Part IV, "Sewage Disposal," has been practically rewritten. In it the author discusses disposal by dilution and the various methods of treatment in use at the present time, with numerous items of cost of work.

On reading this book one misses the lists of references so common in many technical books, and forming such a valuable part of them. It would also seem that, as the book will reach so many city engineers and municipal officials, the author might have given valuable advice as to the keeping of statistics and the preparation of reports. Moreover, one is disappointed at finding so few figures of recent date. For instance, in Table 9, page 30, on maximum amounts of rainfall, there are no figures of storms later than 1896.

The book is well printed, the illustrations are numerous, though rather small, and there is a good index.

SEWAGE DISPOSAL. By Leonard P. Kinnicutt, C.-E. A. Winslow, and R. Winthrop Pratt. 8vo, xxvi + 436 pages. 113 figures. New York: John Wiley & Sons, 1910. Cloth, $3.00 net.

In the preface the authors state that the book is intended to give a general survey of the problems of sewage disposal from the various viewpoints of the chemist, the sanitary biologist, and the engineer, and with particular attention to the conditions of American practice.

The intentions of the authors are well carried out and the book will be found to be of considerable value to students, engineers, and public officials interested in the design, construction, and operation of sewage disposal works.

In the introduction the authors discuss " the sanitary demand for sewerage and sewage disposal," covering briefly the dangers arising from accumulations of excreted material, the various systems of disposal, and their relations to the public health. The chemical composition of sewage is discussed in considerable detail.

The authors then discuss the various methods of treatment, under the headings of dilution, screening and straining, sedimentation, precipitation, septic process, disposal of sludge, broad irrigation and sewage farming, sand filtration, contact beds, trickling filters, sewage disinfection, and the methods of analyzing sewage and sewage effluents.

Under each of these headings there are numerous tables and diagrams showing the results obtained with the various methods of treatment. In many cases costs of the processes are stated.

There are numerous photographs and drawings of existing works and descriptions of the important features in considerable detail. There is a good bibliography.

THE CORROSION OF IRON AND STEEL; A BRIEF TREATISE. By Alfred Lang. 130 pages, 5 x 8 inches. New York: The McGraw-Hill Book Company, 1910. Cloth, $1.00.

The author states in the preface that this essay is in a great measure a compilation and study of the results obtained by other investigators, and is intended as a compendium of the subject suitable for reference.

The book gives a brief statement of the various theories of rusting and corrosion, such as the carbonic acid theory, the hydrogen peroxide theory, and the electrolytic theory, and the effects of various gases and impurities.

One of the most valuable features of the book is the general bibliography of the more important articles on the corrosion of iron and steel.

MEMBERSHIP.

ADDITIONS.

(September 1 to December 1, 1910.)

MEMBERS.

Biladeau, Joseph F.
Superintendent Water Works, Pittsfield, Mass.

Bradley, Richard R.
Assistant Engineer, Board of Water Supply, New York City, West Shokan, N. Y.

Bridges, J. H.
Superintendent Henderson Water Company, Henderson, N. C.

Ellis, George R.
Superintendent Water Department, Canandaigua, N. Y.

Gillespie, Chester G.
1536 Walnut Street, Berkeley, Cal.

Goodell, John M.
239 West Thirty-ninth Street, New York City.

Hannan, William E.
Water Commissioner, Boston, Mass.

Preston, Charles H., Jr.
Civil and Consulting Engineer, 136 Grand Street, Waterbury, Conn.

Smith, Channing
Chairman Cherry Valley and Rochdale Water District, Cherry Valley, Mass.

Smith, Leslie C.
Superintendent Water Works, Cleveland, Ohio.

Titcomb, E. J.
Water Commissioner, Cherry Valley and Rochdale Water District, Rochdale, Mass.

Van Order, Henry B.
Superintendent Water Department, Ithaca, N. Y.

Weller, George L.
Superintendent Water Works, Elyria, N. Y.

Wisner, Martin
50 Highland Avenue, Cambridge, Mass.

ASSOCIATES.

Allyne Brass Foundry Company
Detroit, Mich.

Knickerbocker Engineering Company
21 Park Row, New York City.

Standard Cast Iron Pipe and Foundry Company
Bristol, Pa.

The Goulds Manufacturing Company
Seneca Falls, N. Y.

CHANGES OF ADDRESS.

MEMBERS.

Ayres, J. H.
Care City Engineer's Office, Manila, P. I.

Barnes, T. Howard
Puerto Barnos, Guatemala.

Barnes, William T.
Las Vegas, Mexico.

Bartlett, Charles H.
852 Elm Street, Manchester, N. H., and 60 Pemberton Square, Boston, Mass.

Beardsley, Joseph C.
Card Building, Cleveland, Ohio.

Bemis, Edward W.
106 Hamilton Avenue, New Brighton, Staten Island, N. Y.

Crowley, Robert J.
Member Lowell Water Board, 53 Central Street, Lowell, Mass.

Cutting, George W., Jr.
Care of Construction Quartermaster, Fort Mills, Corregidor, P. I.

Gregory, John H.
Engineer Metropolitan Sewerage Commission, 17 Battery Place, New York City.

Howard, John L.
Engineer's Office, City Hall, Pittsfield, Mass.

King, Arthur C.
43 Jefferson Avenue, Springfield, Mass.

Macksey, Henry V.
11 Gaylord Street, Dorchester, Mass.

Merrill, Andrew S.
414 Pleasant Street, Malden, Mass.

Miller, Hiram A.
14 Beacon Street, Room 507, Boston, Mass.

Miller, Stanley A.
1800 Monroe Street, Paducah, Ky.

Minor, Edward E.
Superintendent New Haven Water Company, 91 Temple Street, New Haven, Conn.

Norcross, Theodore W.
District Engineer, Forest Service, Majestic Building, Denver, Colo.

Perkins, John H.
Antrim, N. H.

Sando, Will J.
Care of Milwaukee Club, Milwaukee, Wis.

Tarbett, Ralph E.
Aspinwall, Pa.

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Superintendent and Chief Engineer, Baltimore County Water and Electric Company, 100–102 West Fayette Street, Baltimore, Md.

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INDEX.

Accounts, water-works, depreciation in, with special reference to uniform reports. By HARVEY S. CHASE. 305–331, June.

Bancroft, Lewis M., Treasurer N E W W A.
Election. 242, March.
Annual report. 234, Mar.
Barnes, H. T. Ice formation. 576, Dec.
Book Reviews.
Text-book on hydraulics. By GEORGE E. RUSSELL. 342, June.
The flow of water: a new theory. By LOUIS SCHMEER. 342, June.
The water supply, sewerage, and plumbing of modern city buildings. By WM. PAUL GERHARD. 343, June.
Sewerage. By A. PRESCOTT FOLWELL. 642, Dec.
Sewage disposal. By KINNICUTT, WINSLOW, and PRATT. 643, Dec.
Corrosion of iron and steel. By ALFRED LANG. 643, Dec.

Caird, James M. The purification plant of the Rochester and Lake Ontario Water Company. 503, Dec.
Chandler, Charles E. Report of committee on damages from water diversion. 1–186, Mar.
Chase, Harvey S. Depreciation in water-works accounting with special reference to uniform reports. 305–331, June.
Choate, Charles F., Jr., Esq. The underlying principles covering riparian water rights and diversion suits. 187–204, March.
Clark, H. W. Double filtration of water. 585, Dec.
Cleaning water mains. Topical discussion. 373–376, Sept.
Coal, the purchase of, on an efficiency basis. By A. O. DOANE. 277–298, June.
Cobb's Hill Reservoir, Rochester, N. Y. By JOHN F. SKINNER. 498, Dec.
Constitution, N E W W A, amendments of. 247, March.
Consumption of water, statistics for, committee appointed to consider. 636, Dec.
Corrosive action of water on metals. By R. S. WESTON. 559, Dec.

Depreciation
In water-works accounts with special reference to uniform reports. By HARVEY S. CHASE. 305–331, June.
In water-works operation and accounting. By LEONARD METCALF. 442, Dec.

Diversion suits, the underlying principles governing riparian water rights and. By CHARLES F. CHOATE, Jr., Esq. 187–204, Mar.
Diversion of water, report of committee on damages from. 1–186, Mar.
Doane, A. O. The purchase of coal on an efficiency basis. 277–298, June.

Elwood, Frederick T. Pertinent matters relating to the Rochester water works. 492, Dec.

Filtration, double, of water. By H. W. CLARK. 585, Dec.
Fisher, Edwin A. Memoranda relative to the city of Rochester, N. Y. 473, Dec.
Forestry. By L. W. GOODRICH. 345–364, Sept.

Gilderson, Dennis H. Obituary. 341, June.
Goodrich, L. W. Forestry. 345–364, Sept.
Gow, F. W. Progress report of committee on standard specifications for post hydrants. 205–220, Mar.
Gowing, Earle Harley. Obituary. 256, Mar.

Hale, Richard A. Report of committee on damages from water diversion. 1–186, Mar.
Hale, Richard K., editor N E W W A.
Annual report. 238, Mar.
Uniform statistics for 1909. 419, Dec.
Hartford, Conn., N E W W A meeting at. 334, June.
Hydrants, progress report of the committee on proposed specifications for post. 205–220, Mar.

Ice formation. By H. T. BARNES. 576, Dec.

Jordan, Frank C. Water-works statistics. 592, Dec.

Kent, Willard, secretary N E W W A.
Election. 242, Mar.
Report of. 231, Mar.
King, George A., president N E W W A.
Portrait. Frontispiece, Mar.
Elected president N E W W A 242, Mar.
Kuichling, E. Steel pipes for water works. 514, Dec.

Lacount, H. O. Progress report of committee on standard specifications for post hydrants. 205–220, Mar.

Laney, C. C. Rochester parks. 482, Dec.
Leighton, Marshall O. Governmental regulation of water powers. 259–276, June.
Library, Committee on, appointed. 641, Dec.
Little, Beekman C. A rambling description of the Rochester water-works. 485, Dec.

McInnes, F. A. Progress report of committee on standard specifications for post hydrants. 205–220, Mar.
Maidstone typhoid epidemic. By W. P. MASON. 299–304, June.
Main, Charles T. Report of committee on damages from diversion of water. 1–186, Mar.
Mains, cleaning water. Topical discussion. 373–376, Sept.
Mason, W. P. The Maidstone typhoid epidemic. 299–304, June.
Metals, the corrosive action of water on. By R. S. WESTON. 559, Dec.
Metcalf, Leonard.
Report of committee on damages from water diversion. 1–186, Mar.
Depreciation in water-works operation and accounting. With Discussion. 442, Dec.
Meters, round multiple and straight reading registers for water. Topical discussion. 370–372, Sept.

N E W W Association.
Address, president's. ROBERT J. THOMAS. 225, Mar.
Amendments of constitution. 247, Mar.
Committees appointed.
Committee on incorporation. 253, Mar.
Arrangements for Providence meeting. 253, Mar.
Arrangements for Hartford meeting. 253, Mar.
To represent the association at Boston, 1915. 254, Mar.
Subject of increased membership. 255, Mar.
Annual convention. 255, Mar.
Statistics for the consumption of water. 636, Dec.
Committee on library. 641, Dec.
Committee reports.
On damages from diversion of water, final report. 1–186, Mar.
On standard hydrant specifications, progress report. 205–220, Mar.
On incorporation. 254, Mar.
Executive committee.
Dec. 8, 1909. 251, Mar.
Jan. 12, 1910. 252, Mar.
Feb. 9, 1910. 254, Mar.
Feb. 16, 1910. 255, Mar.
Mar. 9, 1910. 338, June.
Mar. 24, 1910. 339, June.
April 13, 1910. 339, June.

June 22, 1910. 418, Sept.
Sept. 21, 22, 23, 1910. 639, Dec.
Nov. 9, 1910. 640, Dec.
Dec. 14, 1910. 641, Dec.
Meetings.
Dec. 8, 1909. 221, Mar.
Jan. 12, 1910. 223, Mar.
Feb. 9, 1910. 246, Mar.
Mar. 9, 1910. 332, June.
Apr. 13, 1910 (Hartford, Conn.). 334, June.
June 22, 1910 (Providence, R. I.). 416, Sept.
Sept. 21, 22, 23, 1910 (Rochester, N. Y.). 623, Dec.
Nov. 9, 1910. 633, Dec.
Dec. 14, 1910. 636, Dec.
Reports of officers.
Secretary. (Willard Kent.) 231, Mar.
Treasurer. (L. M. Bancroft.) 234, Mar.
Editor. (R. K. Hale.) 238, Mar.
Uniform statistics for 1909. By RICHARD K. HALE, editor. 419, Dec.

Obituary.
Earle Harley Gowing. 256, Mar.
Dennis H. Gilderson. 241, June.

Parks, Rochester. By C. C. LANEY. 482, Dec.
Pipes, steel, for water works. By E. KUICHLING. 514, Dec.
Providence, R. I., N E W W A meeting at. 416, Sept.
Purification plant of the Rochester and Lake Ontario Water Company.
By JAMES M. CAIRD. 503, Dec.

Reservoir, Cobb's Hill, Rochester, N. Y. By JOHN F. SKINNER. 498, Dec.
Rochester, N. Y.
Memoranda relative to. By EDWIN A. FISHER. 473–482, Dec.
Parks. By C. C. LANEY. 482–485, Dec.
A rambling description of the water works. BEEKMAN C. LITTLE. 485–492, Dec.
Pertinent matters relating to the water works. By FREDERICK T. ELWOOD. 492–498, Dec.
Cobb's Hill Reservoir. By JOHN F. SKINNER. 498–503, Dec.
The purification plant of the Rochester and Lake Ontario Water Company. By JAMES M. CAIRD. 503–514, Dec.
Annual convention held at. 623, Dec.

Secondary water supplies, their dangers and value. Topical discussion. 377–415, Sept.

Services, vibration in house. Topical discussion. 365–369, Sept.
Skinner, John F. Cobb's Hill Reservoir, Rochester, N. Y. 498, Dec.
Specifications, standard, for post hydrants. Progress report of committee on. 205–220, Mar.
Stacy, George A. Progress report of committee on standard specifications for post hydrants. 205–220, Mar.
Statistics.
Damages for water power diversion, report of committee on. 1–186, Mar.
Principal, N E W W A. 230, Mar.
Consumption of water, committee appointed to consider. 636, Dec.
Uniform, for 1909. By RICHARD K. HALE. 419, Dec.
Water works. By F. C. JORDAN. 592, Dec.
Sullivan, W. F. Progress report, report of committee on standard specifications for post hydrants. 205–220, Mar.

Thomas, Robert J. President N E W W A. Address. 225, Mar.
Topical Discussion.
Vibration in house services. 365–369, Sept.
Round multiple and straight reading registers for water meters. 370–372, Sept.
Cleaning water mains. 373–376, Sept.
Secondary water supplies, their dangers and value. 377–415, Sept.
Typhoid, Maidstone, epidemic. By W. P. MASON. 299–304, June.

Vibration in house services. Topical discussion. 365–369, Sept.

Water.
Report of the committee on damages from water, and water power diversion. 1–186, Mar.
Consumption of, statistics for, committee appointed to consider. 636, Dec.
Double filtration of. By H. W. CLARK. 585, Dec.
Water power.
Report of the committee appointed to collect data relating to awards for water and water power diversion. 1–186, Mar.
Governmental regulation of. By MARSHALL O. LEIGHTON. 259–276, June.
Water rights, the underlying principles governing riparian water rights and diversion suits. By CHARLES F. CHOATE, Jr., Esq. 187–204, Mar.
Water supplies, secondary, their dangers and value. Topical discussion. 377–415, Sept.
Weston, Robert Spurr. The corrosive action of water on metals. 559, Dec.
Wheeler, William. Report of committee on damages from water diversion. 1–186, Mar.

Water works.

Uniform statistics for 1909. By RICHARD K. HALE. 419, Dec.

Operation and accounting; depreciation in. By LEONARD METCALF. 442, Dec.

Statistics of income. By F. C. JORDAN. 592, Dec.

Rochester water works. BEEKMAN C. LITTLE. 485, Dec.

Pertinent matters relating to the Rochester. By FREDERICK T. ELWOOD. 492, Dec.

Steel pipes for. By E. KUICHLING. 514, Dec.

INDEX OF ADVERTISERS.

	PAGE.
Ashton Valve Co.	xv
Bond, Harold L. & Co.	xi
Boston Engineers' Supply Co.	xi
Buffalo Meter Co.	xiv
Builders Iron Foundry	xxiii
Cancos M'f'g Co.	xii
Chadwick-Boston Lead Co.	xxiv
Chapman Valve M'f'g Co.	xviii
Clark, H. W. Co.	xii
Coffin Valve Co.	xvii
Conrad, Wm. R.	xii
Cook Well Co.	xxix
Dixon, Jos. Crucible Co.	xii
Donaldson Iron Co.	xxi
Eagle Oil and Supply Co.	xxv
Engineering News, The	xxvi
Engineering Record, The	xxviii
Fox, John & Co.	xiii
Hague, Charles A.	xii
Hays M'f'g Co.	xxvii
Hersey M'f'g Co.	iv
Lead Lined Iron Pipe Co.	xiii
Leadite Co.	xxx
Ludlow Valve M'f'g Co.	xvii
McWane Pipe Works	xxi
Millar, Chas. & Sons Co.	xv
Mueller, H. M'f'g Co.	x
National Meter Co.	ii, iii
National Water Main Cleaning Co.	xx
Neptune Meter Co.	vi
New York Continental Jewell Filtration Co.	ix
Norwood Engineering Co.	xv
Pitometer Company	xii
Pittsburg Meter Co.	vii
Rensselaer M'f'g Co.	xix
Ross Valve M'f'g Co.	xv
Semet-Solvay Co.	xx
Simplex Valve & Meter Co.	xi
Smith, The A. P. M'f'g Co.	xiii
Smith, B F. & Co.	xii
Standard Cast Iron Pipe & Foundry Co.	xxix
Thomson Meter Co.	v
Union Water Meter Co.	ix
U. S. Cast Iron Pipe and Foundry Co.	xxii
Warren Foundry and Machine Co.	xix
Wood, R. D. & Co.	xvi
Worthington, Henry R.	viii

CLASSIFIED DIRECTORY OF ADVERTISEMENTS.

	PAGE.
ARTESIAN AND DRIVEN WELLS.	
Cook Well Co.	xxix
B. F. Smith & Co.	xii
BRASS GOODS.	
Hays M'f'g Co.	xxvii
H. Mueller Mfg. Co.	x
The A. P. Smith M'f'g Co.	xiii
Union Water Meter Co.	ix
CAST IRON PIPE AND SPECIALS.	
Builders Iron Foundry	xxiii
Donaldson Iron Co.	xxi
John Fox & Co.	xiii
McWane Pipe Works	xxi
Chas. Millar & Sons Co.	xv
Standard Cast Iron Pipe & Foundry Co.	xxix
U. S. Cast Iron Pipe and Foundry Co.	xxii
Warren Foundry and Machine Co.	xix
R. D. Wood & Co.	xvi
CLEANING WATER MAINS.	
National Water Main Cleaning Co.	xx

(Index continued on page xxxi.)

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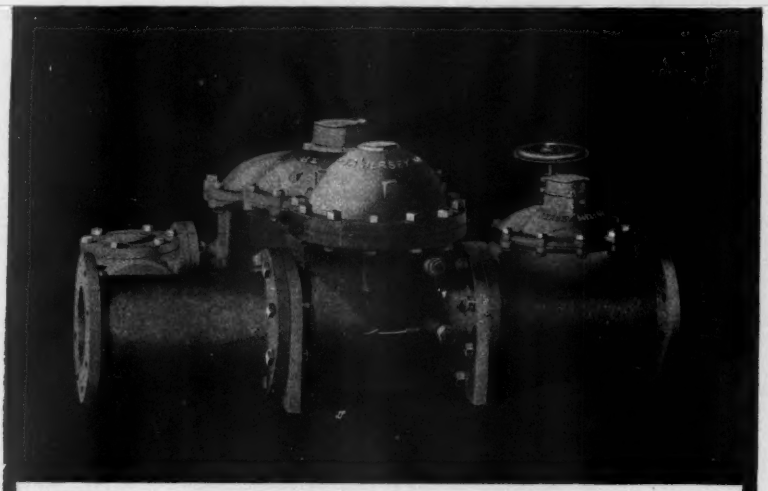

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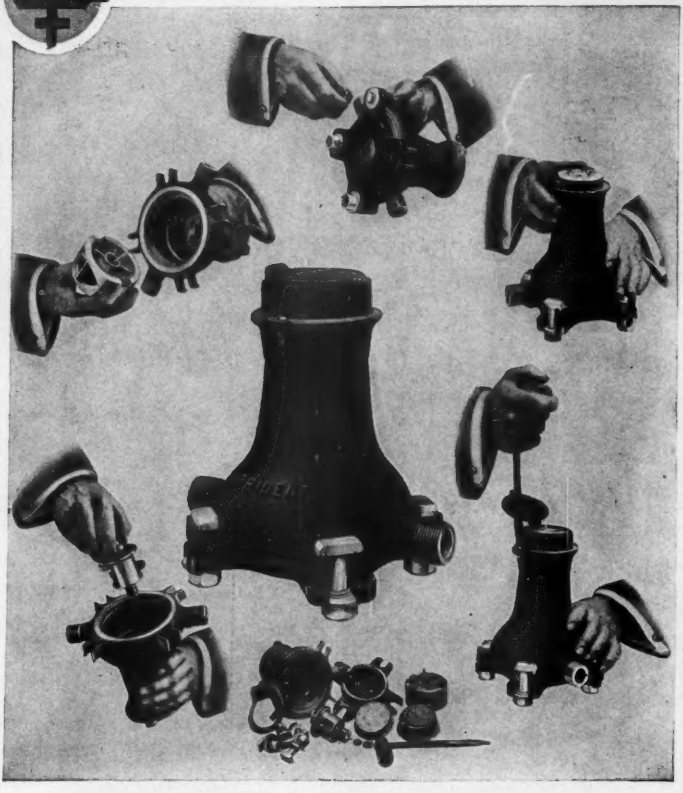

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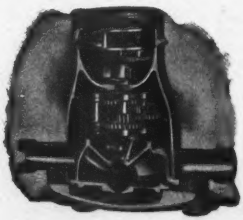

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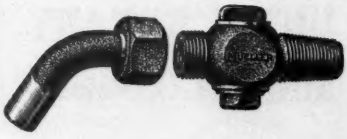

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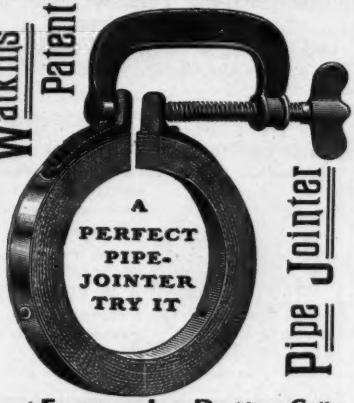

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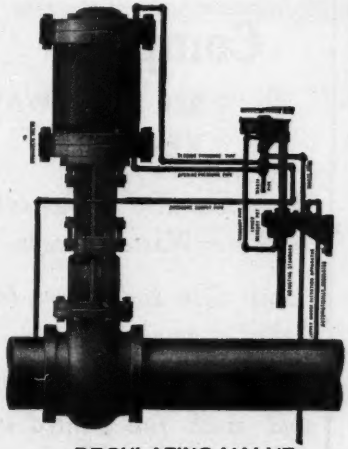

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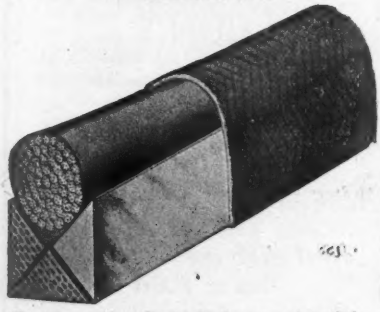

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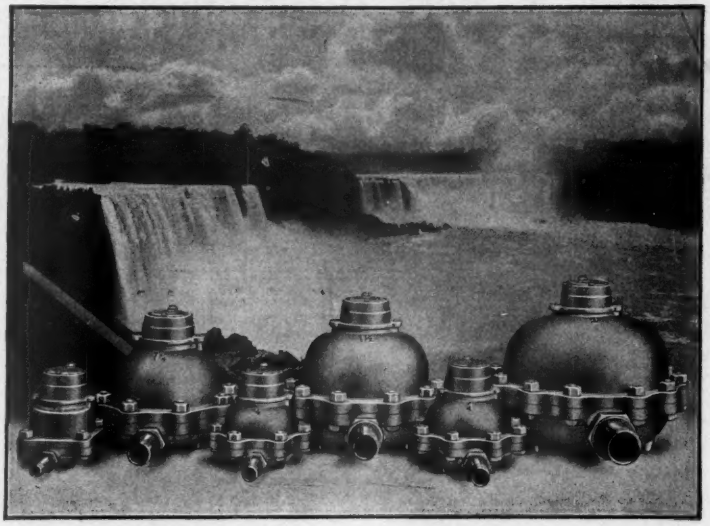

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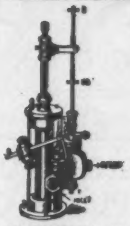

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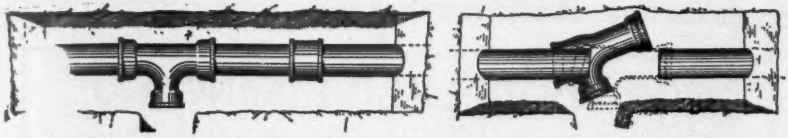

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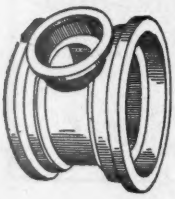

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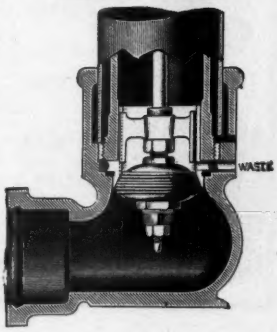

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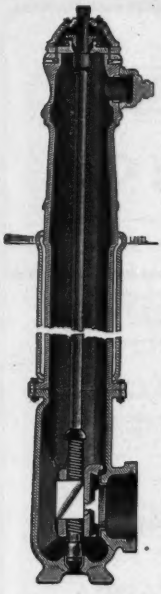

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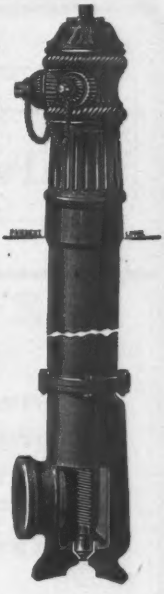

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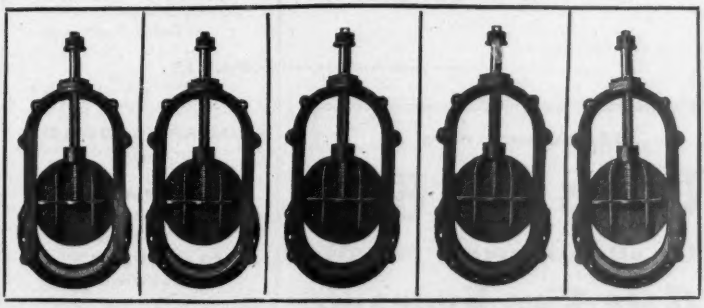

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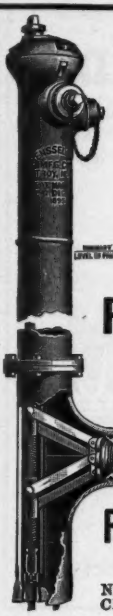

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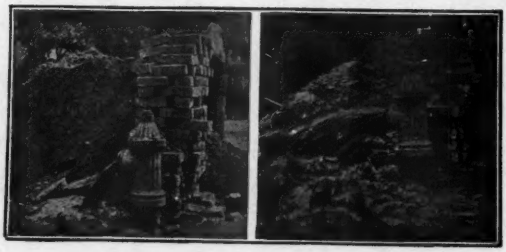

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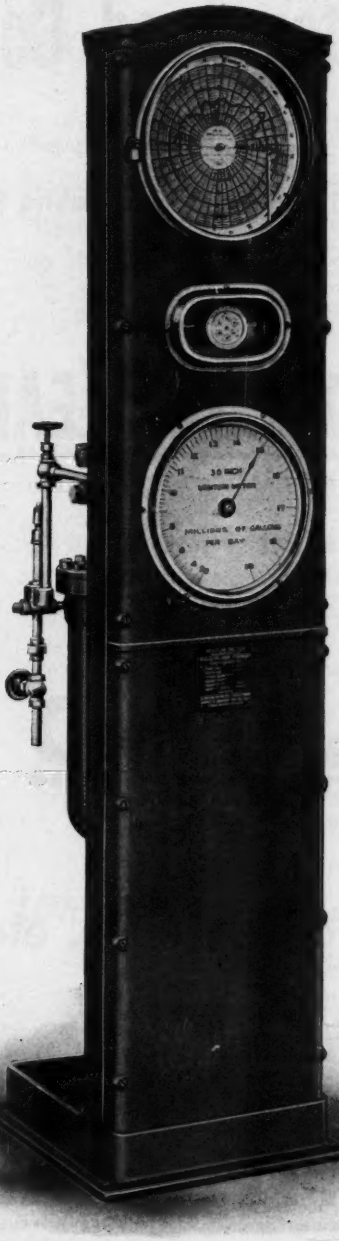

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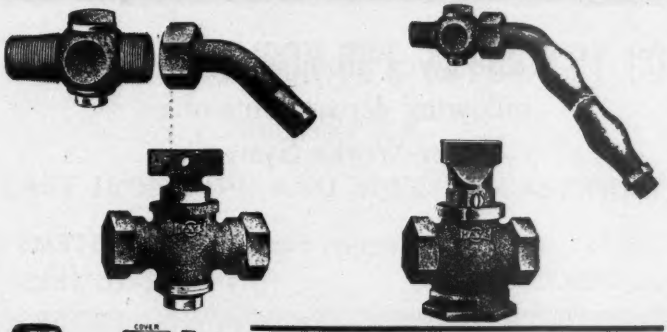

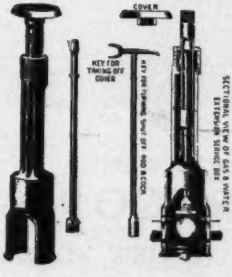

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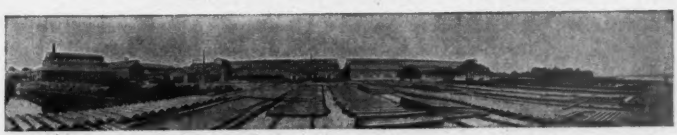

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ENGINEERS. PAGE.

Charles A. Hague xii

FILTERS AND WATER SOFTENING PLANTS.

New York Continental Jewell Filtration Co. ix
Norwood Engineering Co. xv
Ross Valve M'f'g Co. xv

FURNACES, ETC.

H. Mueller Mfg. Co. x
Harold L. Bond & Co. xi
The A. P. Smith M'f'g Co. xiii
The Leadite Co. xxx

GAS ENGINES.

National Meter Co. . . . . .

GATES, VALVES, AND HYDRANTS.

Ashton Valve Co. xv
Chapman Valve M'f'g Co. xviii
Coffin Valve Co. xvii
John Fox & Co. xiii
Ludlow Valve M'f'g Co. xvii
Norwood Engineering Co. xv
Rensselaer M'f'g Co. xix
Ross Valve M'f'g Co. xv
Simplex Valve and Meter Co. xi
The A. P. Smith M'f'g Co. xiii
R. D. Wood & Co. xvi

INSPECTION OF MATERIALS.

Wm. R. Conard xii

LEAD AND PIPE.

Chadwick-Boston Lead Co. xxiv
Lead Lined Iron Pipe Co. xiii

LEADITE.

The Leadite Co. xxx

METERS.

Buffalo Meter Co. xiv
Builders Iron Foundry xxiii
Hersey M'f'g Co. iv
National Meter Co. ii
Neptune Meter Co. vi
Pittsburg Meter Co. vii
Simplex Valve and Meter Co. xi
Thomson Meter Co. v
Union Water Meter Co. ix
Henry R. Worthington viii

METER BOXES.

H. W. Clark Co. xii
Hersey M'f'g Co. iv

OIL, GREASE, ETC.

Boston Engineers' Supply Co. xi
Jos. Dixon Crucible Co. xii
Eagle Oil and Supply Co. xxv

PACKING.

Harold L. Bond & Co. xi
Cancos M'f'g Co xii
Boston Engineers' Supply Co. xi
Eagle Oil and Supply Co. xxv

PAINT.

Eagle Oil and Supply Co. xxv
Semet-Solvay Co. xx

PIPE JOINTS.

The Leadite Co. xxx

PRESSURE REGULATORS.

H. Mueller Mfg. Co. x
Ross Valve M'f'g Co. xv
Simplex Valve and Meter Co. xi
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(*Index continued on page xxxii.*)

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CLASSIFIED DIRECTORY OF ADVERTISEMENTS (*Concluded*).

	PAGE.
PUMPS AND PUMPING ENGINES.	
Builders Iron Foundry	xxiii
Cook Well Co.	xxix
National Meter Co.	iii
R. D. Wood & Co.	xvi
STRAINERS.	
Cook Well Co.	xxix
TAPPING MACHINES.	
H. Mueller Mfg. Co.	x
The A. P. Smith M'f'g Co.	xiii
TOOLS AND SUPPLIES.	
Boston Engineers' Supply Co.	xi
H. Mueller Mfg. Co.	x
Harold L. Bond & Co.	vi
The A. P. Smith M'f'g Co.	xiii
Hays M'f'g Co	xxvii
The Leadite Co.	xxx

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